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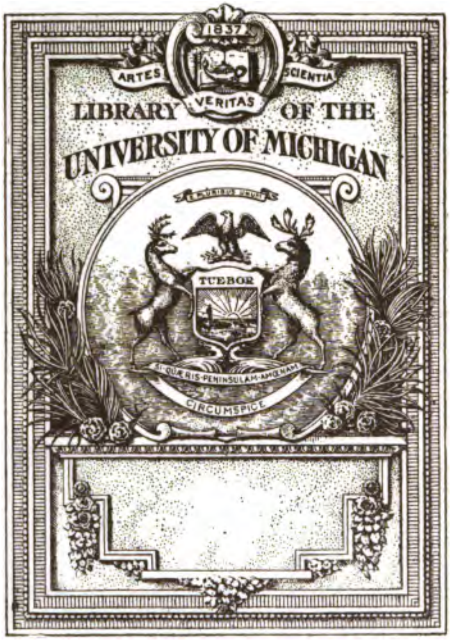
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THE UNIVERSITY OF CHICAGO PUBLICATIONS
IN RELIGIOUS EDUCATION

EDITED BY
ERNEST D. BURTON SHAILER MATHEWS
THEODORE G. SOARES

CONSTRUCTIVE STUDIES

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THE PRESENT TROTTING CHAMPION, UHLAN

THE THIRD *and* FOURTH GENERATION

AN INTRODUCTION TO HEREDITY

By

ELLIOT ROWLAND DOWNING

The School of Education
University of Chicago

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EDITORS' PREFACE

The curriculum of the church school of religious education is rapidly widening. This does not mean that the study of the Bible is decreasing, but that more time is devoted to the study of the religious significance of life. A variety of important subjects dealing with social and ethical problems is occupying the attention of young men's and young women's classes and of young people's clubs and societies. Bible study becomes more significant as it takes its place among all the human interests.

The public school is recognizing its responsibility for larger social education and, wherever young people are receiving adequate instruction in the duties of modern life the task of the church is so far lightened. But there are many social studies which are peculiarly well undertaken in the religious atmosphere; and there is a very large body of young people in the

326080

churches who have never completed a high-school education and for whom the church has important educational responsibility. Therefore, without in any wise undertaking to parallel the work of the high school, the curriculum of religious education may well include a wide range of social studies.

For these reasons the scheme of the Constructive Studies has contemplated very much more than the biblical elements. Beginning with Henderson's *Social Duties from the Christian Point of View* a series of textbooks dealing with important social problems has been gradually developed.

The present study is an attempt to consider frankly and seriously the scientific facts regarding the problem commonly called "eugenics." The religious significance of a reverent and thoughtful understanding of this highly interesting subject is at once apparent when one thinks of the perfecting of human society as the goal of the divine plan. The scientist, as such, will not of course discuss the spiritual significance of the evolutionary goal. That is where faith

goes beyond our ascertained knowledge. But faith must not operate apart from knowledge. Nothing can be more important in religious education than to train young people to use the careful methods of science in ascertaining the facts upon which their conclusions, not less in morals and religion than in other fields, are always to be based. The author of this volume is a most successful teacher, and he has succeeded in presenting the technical aspects of the subject in a simple and popular way.

While the book has been prepared for young people's classes, the editors would commend it to the reading of ministers and laymen who are desirous of obtaining in untechnical language the results which scholars have arrived at in this modern attack upon the problem of evolution.

CONTENTS

CHAPTER I

INTRODUCTION

Scientists have accumulated more accurate information regarding the laws and the physical basis of heredity in the last fifty years than the world acquired in the preceding fifty centuries. Indeed the most important part of this knowledge has come to light within two decades. Moreover it is knowledge of immense practical value, the sort that will certainly affect human life and racial destiny. This does not imply that all the problems of heredity are settled or that our knowledge of its laws is complete: far from it. No one realizes as well as the student of these phenomena how fragmentary and incomplete is our present knowledge, but enough has been achieved to afford some rational foundation for human action. It is generally recognized that important discoveries have recently been made along these lines, but the prevailing ideas regarding these and their

import are hazy and misleading. It seems wise therefore to present the new data simply that as common knowledge they may become a basis of wise individual conduct and may help mold public opinion on some important social questions.

This book is intended primarily for young people. They can most readily break away from the whims and prejudices of the past and adopt a new set of ideas as adequate grounds for new habits. They live only in this scientific age when we have an increasing respect for facts, reason on them to correct conclusions, and base on them our sense of duty. They are practical optimists, and what seems an impossible dream of the visionary to an older generation, hidebound by preconceived notions and social traditions, comes to be, for valorous youth, a simple accomplishment dictated by good sense.

It has been the aim to make the presentation as simple and non-technical as possible. So many of the concepts dealt with are rather new to the average reader that some of the chapters at least will need study rather than mere read-

ing. The book used in classes or reading circles does not presuppose a teacher who is already familiar with the subject-matter, merely one who is willing to re-read and think until the matter becomes reasonably clear. It is suggested that after reading each chapter individually the group should come together to discuss the content. The appended list of books will be an aid to those who wish to read more widely on the topics presented or who wish to prepare reports for the class on particularly interesting phases of the subject.

CHAPTER II

SOME FAMOUS RACERS AND THE PROBLEMS THEY SUGGEST

Every red-blooded individual is frankly interested in horse races, stock shows, boxing bouts, billiard matches, tennis tournaments, battles, and wars. The race has spent so much of its history in the struggle to get on that anything which pertains to physical fitness and mental alertness stirs deep-seated fibers of our being. A fine specimen of a horse, a blooded milch cow with a record for butter-fat production, a champion tennis player who has successfully pitted wit and skill against keen rivals, a victorious army, all make insistent appeal and receive our admiration, even our homage. We recognize that back of the winning performance there is a record of racial improvement and individual development which required the exercise of many admirable traits.

In seventy years the record for the trotted mile has been reduced from 2:24½ to 1:54–, an

improvement of nearly 30 per cent. There is given in Table I the list of American horses that have successively lowered the record.

TABLE I

Flora Temple	1845–59	2:24½ to 2:19¾
Dexter	1867	2:17¾
Goldsmith Maid	1872	2:16¾
Occident	1873	2:16¾
Goldsmith Maid	1874	2:14
Rarus	1878	2:13¾
St. Julien	1879	2:12¾
Maud S.	1880	2:11¾
St. Julien	1880	2:11¼
Maud S.	1880	2:10¾
Maud S.	1881	2:10¼
Jay Eye See	1884	2:10
Maud S.	1884	2:09¾
Maud S.	1885	2:08¾
Sunol	1886	2:08¼
Nancy Hanks	1892	2:04
Alix	1893	2:03¾
The Abbot	1900	2:03¼
Cresceus	1901	2:02¼
Lou Dillon	1903	2:00
Cresceus	1903	1:59¾
Lou Dillon	1905	1:58½
Uhlan	1913	1:54*

*Without windshield or running pace setter 1:58.

What are the factors which, since the days of Flora Temple, have brought about the marked improvement that enables the present champion to do the mile in less than two minutes? Some of them are very evident.

More than four seconds was clipped from the record when, in 1892, the bicycle sulky replaced the old wooden affair. Some of the increased speed is undoubtedly due to the improvement in the race track and in methods of training. But these are not all, and probably not the most important factors, else a skilful trainer should be able to harness any horse to a modern sulky and get racing speed out of him.

Racing speed seems to be in the blood. Look up the ancestry of this list of record-breaking racers and you will be struck at once by the recurrence, time after time, of a few famous breeding animals in the pedigree of nearly all of them. Notice the ancestry of Alix, a horse chosen because it is possible to trace his pedigree much more completely from available sources than that of most of the others. Even so, only 290 of his ancestors have been found out of a possible 1,022 back to the ninth generation (2 parents+4 grand-parents+8 great-grandparents+16+32+64+128+256+512=1,022). Out of these known 290 Imported Messenger occurs 33 times, his

- Atalanta
  - Attorney
    - Enchantress
      - Abdullah I
        - Mambrino
          - *Messenger*
            - Sour Crout
              - Highflyer
              - Slammerkin
            - ....
              - Whirligig
              - ....
          - ....
        - Amazonia
          - Paymaster
            - *Messenger*
            - ....
          - ....
      - Miss Russel
        - Pilot, Jr.
          - Pilot
            - Havoc
              - Sir Charles
              - ....
            - ....
          - Nancy Pope
        - Sally Russel
          - Boston
            - Timoleon
            - Sister to Tuckahoe
          - ....
    - Maud
      - Alexander's Abdullah 15
        - Hambletonian 10
          - Abdullah I
            - Mambrino
              - *Messenger*
                - Sour Crout
                - ....
              - ....
            - Amazonia
              - Paymaster
                - *Messenger*
                - ....
              - ....
          - Chas. Kent's Mare
            - Bellfounder 55
              - Old Bellfounder
                - Pretender
                - ....
              - Velocity
            - Old One Eye
              - Bishop's Hambletonian
                - *Messenger*
                - Pheasant
              - Silvertail
                - *Messenger*
                - Jim Black
        - Katy Darling
          - Bay Roman
          - ....
      - ....
  - Flirt
    - General Hatch
      - Cassius Clay, Jr., 22
        - Cassius Clay 18
          - Henry Clay 8
            - Andrew Jackson
              - Young Bashaw
                - Grand Bashaw
                - Pearl
              - ....
            - Lady Surrey
          - Jersey Kate
        - ....
          - Abdullah I
            - Mambrino
              - *Messenger*
              - ....
            - Amazonia
              - Paymaster
                - *Messenger*
              - ....
          - Amazonia
            - Paymaster
              - *Messenger*
              - ....
            - ....
      - ....
        - Envoy
        - ....
    - Dolly
      - Iowa
        - Glencoe
        - ....
      - Dolly Aldrich

parents or grandparents 64 times. Or, to put the matter in another way, out of 96 known animals in the ninth generation of Alix' pedigree, Messenger, his parents and grandparents make up 65. If the same holds true for the unknown lines of ancestry, Alix is at least 60 per cent Messenger blood.

Imported Messenger was an English stallion brought into this country in 1788; he traces back to Godolphin Arabian and Darley Arabian, from which stock England's best racers are derived. Many of the other animals in this ninth generation of Alix' ancestry, such as Diomed, Fireaway, and Highflyer, also come from these same Arabians.

If the male line is traced in all recorded American trotters, going back of the sire to the grandsire, to the great-grandsire, and so on, it is found that out of 22,238 animals registered to the end of 1906, 16,495 descended "in tail-male"—as this particular line of descent is designated—from Imported Messenger; 170 out of the 180 trotters of the 2:10 class are also so derived from him, and 146 out of 150 of the

most famous pacers are taken from him "in the tail-male line."

It seems very evident from the study of such pedigrees that ability to produce exceptional speed on the track runs in families and that pride in ancestry is perfectly justifiable among race horses. The same thing is apparent if we consider any other animal ability, such as milk production in cows, pointing in dogs, or honey production in bees. Thus in the case of King Melia Rioter 14, a famous Jersey bull, sire of splendidly productive milkers, the same animals have so often reappeared repeatedly in the ancestry of both sire and dam, as is seen in the partial pedigree below, that he is more than 90 per cent (93.85) inbred. If an animal were derived from the offspring of a mating of brother and sister, he would be considered 100 per cent inbred.

The breeder appears to be trying, either by skill or luck, to sort and recombine the elements that enter into successful animals and that make for efficiency, taking this trait from one strain, that from another, and uniting them

PEDIGREE OF KING MELIA RIOTER 14

*103901 King Melia Rioter 14	73104 *King Melia Rioter*	63200 *Marjorie Melia Ann's Son*	56581 *Melia Ann's King*	22041 *Melia Ann's Son*
				100775 Lottie Melia Ann
			157263 *Marjorie Melia Ann*	22041 *Melia Ann's Son*
				905883 Mary Melia Ann
		181544 *Letty's Silver Hair*	58169 *King of All Kings*	54896 *St. Lambert's Rioter King*
				114804 St. Lambert's Letty
			148456 *Exile's Silver Hair*	32559 Exile of St. Ann's
				60449 Silver Hair 4
	262926 Larissa Marie	73104 *King Melia Rioter*	63200 *Marjorie Melia Ann's Son*	56581 *Melia Ann's King*
				157263 *Marjorie Melia Ann*
			181544 *Letty's Silver Hair*	58169 *King of All Kings*
				148156 *Exile's Silver Hair*
		219360 Dula Riotress' Maid	62098 King Rioter's Lad	54896 *St. Lambert's Rioter King*
				142296 King's Riotress Nora
			218796 St. Lambert's Dula Riotress	57778 St. Lambert's Boy
				174761 Rioter Lad's First Daughter

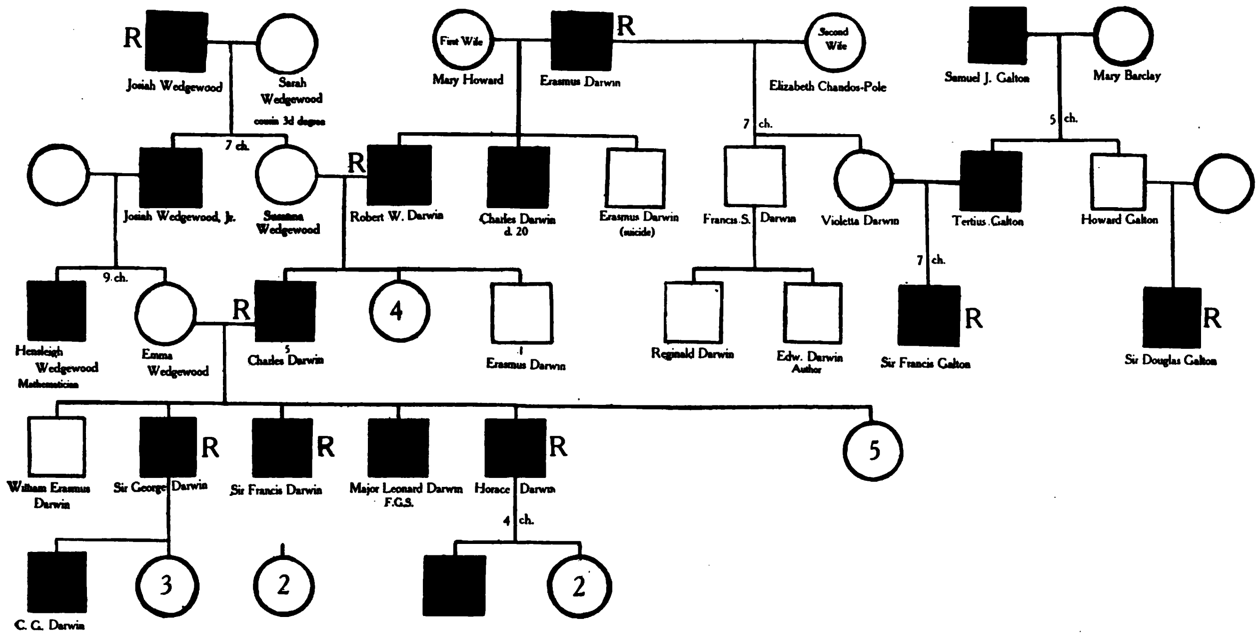
(Animals whose names are in italics appear more than once in the pedigree.)

* Pedigree after Pearl, *American Naturalist*, XLVIII.

in a new combination with the hope of producing a still better type.

There seems to be abundant evidence that ability similarly runs in human families. Here is given the chart of family connections in the Darwin-Wedgewood-Galton family (see Plate I). This tabulation traces the lines back to Josiah Wedgewood, founder of the famous potteries, to Erasmus Darwin, philosopher and author, and to Samuel Galton. All three were men of marked distinction, the first two members of the Royal Society. Men of marked ability are indicated in the chart by black squares; those who, in addition, are members of the Royal Society are shown with an R beside the square. There is unfortunately no criterion for judging the degree of distinction of the women (represented by circles) as exists in biographical dictionaries or membership in learned societies for men. Charles Darwin, one of the most noted of biologists, himself a member of the Royal Society, comes from a father who was a member and from grandfathers both of whom were also members of the same distinguished organi-

PLATE I



THE DARWIN-WEDGEWOOD-GALTON FAMILY

Males of note, black squares; an R beside square shows membership in one of the Royal Societies. Figures in circles show number of daughters if more than one.

zation. His wife comes from equally able parentage. Three of their sons were also members of the Royal Society, one of the Royal Geographic Society; two of their grandsons are already men of marked ability.

The son of an able man is much more likely to display ability than the average person. Sir Francis Galton, in the above-mentioned family, devoted his life to studies of human heredity. In his book on *Heredity Genius* he gives some of the important results of his studies. He looked up the family connections of all the great English judges who lived in the period from 1660–1865. There were 268 of them of sufficient distinction to be included in Foss's *Lives of the Judges;* 109 of these had one or more eminent relatives. Close relatives were more likely to be eminent than distant relatives. C. W. Saleeby in his *Parenthood and Race Culture* reduces Galton's results to the following statement: sons of judges have 126 chances out of 1,000 of achieving greatness, brothers 82, grandsons 37, and nephews 17. To give these figures any significance we must

know what the chance is for the average man. Galton calculated this, too. He assumed that a man would display marked ability by fifty years of age if he was ever going to do so. So by comparing the number of men in the English *Men of the Time*, later known as *Who's Who*, with the total number of Englishmen of fifty or more he found the chance of the average man to achieve distinction to be 1 to 4,000. So the son of a judge is 500 times as likely to display ability as the son of the average man, which Galton thinks is due in large part to his inheritance. Galton's investigation included not only judges, but also scientists, artists, statesmen, and others, embracing in its scope nearly a thousand families. The conclusions reached substantiate those given for the judges.

There is given here the family tree of the Bach family, of which Johann Sebastian Bach, organist and composer, was the most noted. The family sprang from well-to-do Thuringian peasant stock that manifested marked musical ability even before the records are sufficiently accurate to show what relation these early talented indi-

viduals were to Sebastian's immediate ancestry. In six generations there appeared 57 musicians of repute, 29 of whom were really noted.

The best-known illustration of inherited ability in American families is found in the descendants of Jonathan Edwards, and there is usually contrasted with this Edwards family of noted people a contemporaneous but notorious family, known as the Max-Jukes, whose pedigree was traced to 1874 in detail by R. A. Dugdale and to 1915 by Estabrook. Dugdale's data were published in the *Twentieth Annual Report of the New York State Prison Commission*, later appearing as a book from the press of G. P. Putnam's Sons. The results of Estabrook's investigations appear as a publication of the Carnegie Institution, Washington, D.C. The contrasting records of the two families are given below:

Jonathan Edwards' Descendants

1,394 descendants traced in 1900

Not a pauper among them but many professional men, including:

60 physicians

60 or more authors
100 or more ministers and missionaries
100 lawyers
75 army officers
295 college graduates
13 college presidents

Max-Jukes's Descendants

About 1,200 known in 1874; 2,094 to 1915
1,258 now living in this country
310 paupers (Dugdale)
Over 600 of those living are feeble-minded or epileptic (Estabrook)
More than 300 immoral women (Dugdale)
140 criminals, 7 murderers
Not a soldier among them
Not one had a common-school education
Only 20 learned a trade, 10 of those in prison
The family has cost society over $2,500,000

Similar contrasts are undoubtedly to be found in many other families, but this one has been carefully worked out. Jonathan Edwards (1703–58), whom Daniel Webster called the most brilliant logician America has produced, came of Welsh stock. His great-great-grandfather was a prominent clergyman of London in the

days of Shakespeare and Bacon. The son of this clergyman came to the New England colonies and was a prosperous merchant of Hartford, Connecticut, as was his only son, Richard. This Richard's wife was Mary Tuttle, a commanding and brilliant woman. Their only son, Timothy, was a clergyman, a Harvard honor man, the father of eleven children, of whom the fifth was Jonathan. Jonathan's mother as well as his wife were from fine types of American families.

The Max-Jukes family originated in Sullivan County, New York, into which isolated region, to quote Dugdale's account, "now within two hours' rail journey of the nation's metropolis, there drifted nearly a century and a half ago a number of persons whose constitutions did not fit them for participation in a highly organized society: Max, the hunter and fisher, the jolly, alcoholic ne'er-do-well; Lem, the stealer of sheep; Lawrence, the licentious, free with his gun; Margaret and Delia, the wantons, and Belle who had three children by various negroes." From this bad stock has come the

strain known as the Max-Jukes, and whether the descendants are found in Connecticut, in New Jersey, or even in Minnesota, they manifest the same feeble-mindedness, indolence, licentiousness, and dishonesty.

In the foregoing case as well as in the family history of the Darwins and the Bachs there is considerable inbreeding, that is, mating between individuals that are closly related. Such matings are intentionally carried out by the breeder in the production of fine horses and cattle, as seen in the pedigrees already given. They seem to serve to emphasize what is in the strain. If superior stock is used, inbreeding merely prevents its dilution. If poor stock is used, the inferior qualities continually reappear in the offspring. Three of the four children of Ada Jukes married cousins, with appalling results. Charles Darwin married a cousin, as did also his grandfather Wedgewood. Johann Sebastian Bach was twice married, each time to a Bach. The Darwin and Bach children manifest the same desirable qualities as the parents.

In all such cases as that of the Jukes and Edwards families we cannot be sure that the unlike environments in which the children were reared may not have been in large measure responsible for the strikingly different character of the offspring. Although the families were contemporaries and lived in adjoining states, yet the home atmospheres, the real environmental influences, were diametrically opposite. This brings up the much-debated question as to which is the more potent, environment or heredity. Such a question is about as sane as whether wind or water is the more important in the production of the waves that surge in along the ocean shore. The simple fact is, the destiny of the individual is the resultant of heredity (what he is), environment (what he has), and training (what he does), and no one element can be omitted in calculating the results. The object of this book is to show how important heredity is and in what ways it is important.

QUESTIONS

1. Consider carefully the reduction in time for the trotted mile since the days of Flora Temple. Estimate

the influence of changes in racing paraphernalia that have helped to bring about the improvement. What facts seem to show that racing ability is in the blood?

2. Is there evidence that ability in other animal activities is similarly heritable?

3. Can you discover human pedigrees other than those cited in this chapter that illustrate the matter under discussion?

4. What seems to you to be the value of the Wedgewood-Darwin-Galton family tree as showing that ability is transmitted from parent to offspring in human families?

5. Will you summarize the data Galton accumulated from the study of the families of English judges and state your judgment as to how far the child of able parents is more likely to display ability than the child of average parents?

6. What do you think is the meaning of the contrast in the achievements of the descendants of Jonathan Edwards and of Max Jukes?

7. What would be your conclusion from the facts given in the chapter?

CHAPTER III

MALE AND FEMALE

The phenomena of heredity, in all the higher plants and animals, are so closely linked with the process of sexual reproduction that it will be well to review here the simple and familiar phases of this process.

Recall the parts of any familiar flower, or, better still, re-examine some one that is at hand, such as the May apple, cherry, or garden pea. The May apple or mandrake flower is a large creamy bloom (Fig. 1) with from six to nine conspicuous white leaflike parts, the petals, that in the bud protect the more essential inner organs. Outside of these petals are three greenish sepals, also leaflike and protective. The essential organs at the center of the blossom are the stamens and the pistil. The latter is quite large, is green and shaped like a tenpin or Indian club, with a very short neck. The stamens each consist of a

stalk or filament that bears at its upper end a yellow case, the anther. Similar parts will be found with varying number and arrangement

FIG. 1.—The mandrake blossom

in almost any flower. They are shown in the figure here.

If the swollen basal part of the pistil is cut open, it will be seen to contain, in either the mandrake or the garden pea, a number of small bodies which you are inclined to call the seeds.

They are not such as yet, however, though they may later develop into seeds. They are called ovules, and in each one, in the newly opened flower, there is to be found an egg, a speck of living substance which may later produce the little plant within the seed. The egg is so small that it is seen only with the aid of a microscope. The swollen base of the pistil is known as the ovary, the name given to the part in plant or animal in which the eggs are formed.

When the term "egg" is used the average person thinks first of a hen's egg or possibly of some other bird's egg as the best known type. But a hen's egg is really much more than a simple egg; it is also a great mass of nutritive material inclosed in a shell to nourish and protect the little chick. If a hen's egg is laid on the table and allowed to stand for a few minutes, and the shell is then cut open with a pair of fine-pointed scissors and the portion of the shell above the yolk is removed, there will be seen floating on the yolk a little fleck of translucent substance, like a bit of jelly (Fig. 2).

It is from this tiny speck of living substance that the chick develops, and this is quite comparable to the egg that the plant ovule contains.

But neither the hen's egg nor the plant egg will develop into the new individual—plant or chick—unless it is fertilized. The anthers on

FIG. 2.—The hen's egg opened

the stamens contain a yellow powder, the pollen, the grains of which are often wonderfully beautiful. Each grain is really a living cell made of the same sort of substance that also constitutes the egg. You will recall this yellow dust in the case of the Easter lily, in which it is very conspicuous; and probably as a child you have stuck your nose into some flower on purpose to get it dusted with the yellow pollen.

Some of the pollen is carried by the wind or by insects to the sticky or hairy upper end of the pistil, called the stigma. The pollen grains each thrust out a tiny thread of their living substance, finer than a hair, that grows down through the tissue of the pistil until it reaches an ovule (Fig. 3). The thread penetrates the ovule and grows into the egg. Then a part of the living substance of the pollen grain unites with the living substance of the egg. This is called fertilization.

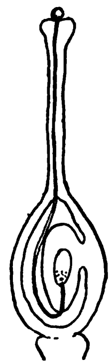


FIG. 3.—Diagram of the fertilization process.

It is only after this has been accomplished that the egg proceeds to grow into the little plant. The fertilized egg divides and subdivides and the resulting cells grow larger. Subdivision and growth continue until a mass of many, many cells is formed. The mass changes shape and molds itself into the little leaves and bud and stem that constitute the embryonic plant. Meanwhile the rest

of the ovule has also changed; it has developed nutritive material and tough coats about the plantlet, and so has helped form the seed. The ovary enlarges and possibly unites with other floral parts to form the fruit (Fig. 4). In shelling peas one often sees within the pod, in

FIG. 4.—Pistil of mandrake enlarging to form the fruit; cross-section at the right.

addition to the fully developed peas, some tiny objects, each attached where you would expect a pea to grow; but these are not so large as the head of a pin. Such are ovules containing eggs that failed to develop because of the lack of adequate fertilization.

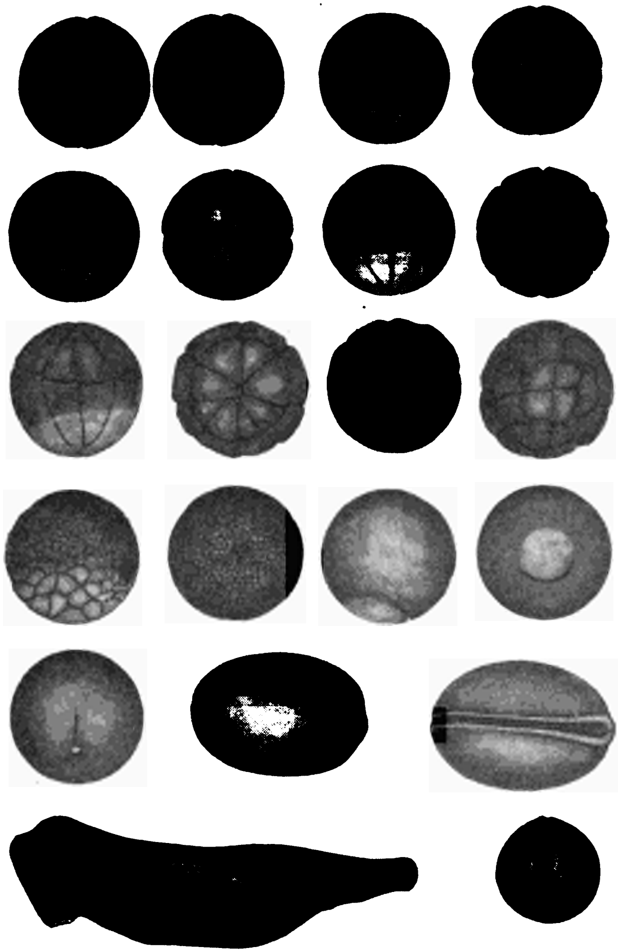
It is difficult to watch the egg develop into the embryo in the plant, for it is hidden in the

ovary. But the process may be followed with ease in the case of the frog's egg or the toad's egg, easily obtained in spring. The eggs of these animals are formed in the ovaries during the fall and winter months. They are discharged by the female frogs in masses almost as soon as the ice is gone from the ponds and in strings by the toad about a month later. When discharged they are spherical bodies as large as the head of an ordinary pin, black on one side and white on the other. As they lie in pond or stream the black side is uppermost.

The female lays her eggs early in the morning, and at the same time the male discharges into the water the sperm produced by glands called the testes. Each sperm is a single living cell with a vibratile tail by which it swims to the egg. The sperms are so small they can only be seen under the microscope. A sperm unites with an egg after the same manner as the fleck of living substance from the pollen grain combines with the substance of the egg, and it is only when this fertilization is accomplished that the egg proceeds to grow into the little tadpole.

When the eggs are laid each is inclosed in a capsule of jelly, so sticky that adjacent eggs adhere in masses or, in the case of the toad, in strings. The masses are as large as the clenched fist of a child and are found attached to grass stems, rushes, or twigs in the shallow parts of the ponds. Frogs seem to have regular egg-laying bees, so that one often finds a peck or more of egg masses at one favorite spot. Sometimes the sedgy margin of a stream will be festooned for rods with floating strings of toads' eggs. But you must be out collecting early in the morning if you would catch the eggs by the time the first division is accomplished. This first plane of cleavage runs from the dark pole to the light, and each little black bead separates into two that lie in close contact, two adherent cells in place of the one (Plate II). In the cold ice water of the pond development goes on rather slowly, but if the eggs are brought into the house in some of the pond water they proceed to cleave rapidly as they become warmer. Two cells become four in an hour or less, four change to eight in still less time,

PLATE II



THE DEVELOPMENT OF THE FROG'S EGG

The upper sixteen figures are in pairs, the left one showing a side view, the right a top view, of one stage. Lower left-hand figure, a newly hatched tadpole. Above it, an end and side view of an earlier stage. At right, a back and end view of stage showing developing spinal cord and brain.

and so the process continues until by night each egg may have changed into a little spherical mass of perhaps a hundred or more cells. Meanwhile this mass of cells is growing larger. In the course of a couple of days it elongates and one can begin to make out the difference between future head and body. In another day the little tadpoles begin to wiggle out of the jelly, and soon they are swimming about seeking food. How they grow, develop legs, and absorb their tails as they change to the adult frog is known to almost every boy and girl, but it is a process that is always watched with interest. This change from a fishlike creature that swims in the water and feeds on vegetable matter to an insect-eating, air-breathing animal is one of the everyday marvels. The whole life-history, briefly outlined above, may be seen if a few of the eggs in their jelly are put into a quart fruit jar or other convenient dish that is a third full of water together with some of the green water weeds found growing in the pond or stream. When the tadpoles are fairly good sized the water should be reduced in amount so it is

only an inch deep, and some clean sand should be added, so the animals can wiggle up out of the water on to the sand at one side of the dish.

What has been described in particular for the mandrake and the frog is a universal process among the common plants and animals with which you are familiar. There is a process of reproduction among the lower forms of life by which the adult becomes two or more young by simply dividing into parts, each of which is remodeled into a perfect animal or plant, as the case may be. But in all higher types it is almost universally true that the young are produced from eggs which must be fertilized by the sperm before they will begin to develop. It is evident that the offspring is the joint product of the two parents, a union of two distinct lines of hereditary descent, and as such may manifest characters peculiar to each.

QUESTIONS

1. Have you ever found frogs' eggs or toads' eggs? Can you describe them?

2. Have you found the eggs of other animals, like flies or turtles or fish? If so, where?

3. Will you draw from memory some flower you know, like the nasturtium or the tiger lily, to show the parts of the blossom? Show by the drawing where the eggs lie in the flower.

4. Make a statement to show how important the egg is in the life-history of a plant or animal.

5. What is the importance of fertilization?

6. By what process does the fertilized egg grow toward the adult individual?

7. What is the value of having the new individual come from two lines of ancestry?

CHAPTER IV

SOME LAWS OF HEREDITY

Some of the phenomena of heredity are so conspicuous that they are evident to everyone; yet they are so commonplace that we pass them by without appreciating their significance. That like reproduces like is a fundamental conception in practice as well as in theory. The hen is set on a clutch of her eggs with every assurance that chickens will hatch. Men do not "gather figs of thistles," and that which is sown we expect to reap. It is furthermore well known that particular traits or features may appear as family characteristics. In one of the royal families of Europe, the Hapsburg family, a prominent jaw and full lips were so marked that "the Hapsburg jaw" was almost a mark of royalty. Such traits or features may occasionally skip a generation to reappear in some later member of the family. The child may resemble a grandparent or an uncle.

Breeders have known that stock must be kept pure to maintain its valuable characters, but new combinations of desirable qualities have been achieved by chance rather than by skill. It is only within this century that our knowledge of heredity has advanced from such hazy notions to the rudiments of the laws that govern the complicated phenomena.

In the middle of the last century an Austrian monk named Gregor Mendel, teacher of science in a monastic school at Brünn, became imbued with the idea that mankind must have some definite knowledge of the laws of heredity as a working basis for the improvement of grains and fruits, of the breeds of cattle, and even of human kind. He decided to experiment with garden peas in an endeavor to ascertain these laws. He was measurably successful and described his results in the *Proceedings of the Scientific Society of Brünn* (1866). The paper attracted no immediate attention in the scientific world, for the volume in which it was published was rather obscure and biologists were just then absorbed in Darwin's startling

theories of the origin of species. In 1900 three other investigators, Hugo de Vries, a Hollander, Correns, and Tschermak, working independently, arrived at much the same results that Mendel had reached. In reviewing the literature of the subject de Vries unearthed Mendel's publication, and the later discoverers promptly gave the credit of priority to Gregor Mendel. So the formulated statement of the way in which many characters behave in hereditary transmission is still called Mendel's law.

Some pea vines bear peas that are quite green when ripe, others produce those that are a distinct yellow. Mendel used a plant of each of these two sorts as parents, cross-pollinating them carefully. The process is now accomplished somewhat in the following way. Just before the flower buds are ready to open, some of them are opened by hand on each sort of vine and the anthers removed. Such blossoms are then powerless to discharge pollen on to their own stigmas. Small paper bags are tied over these flowers so that no other pollen can accidentally get to them by wind or

insect visitor. When later these buds open in the usual way, showing thereby that their pistils are ripe and ready for pollination, a small brush is touched to the pollen-bearing anthers of a normal flower on a vine that will bear yellow peas, and then this pollen is dusted on to the stigmas of the bagged blossoms on the vines that would naturally bear green peas. In a similar way the bagged blossoms on the vines that would normally bear yellow peas are pollinated with the pollen from those bearing green peas. The bag is removed from the flower only long enough to apply the pollen with the little brush, and then it is left in place so that no other pollen can get on to confuse the results.

When the peas formed in the pods that grew from these cross-pollinated parent blossoms in Mendel's experiment, they were all of the yellow sort. These were then planted and the blossoms on the resulting vines (the children) were allowed to pollinate freely, just as they do ordinarily in the garden. The peas that now formed (grandchildren) on these plants

were, surprisingly, of the two sorts again, the green and the yellow. Moreover, of the 8,023 peas so produced 2,001 were green, which makes the proportion of yellow peas to green peas almost exactly 3 to 1. Mendel tried a similar experiment with vines that grew about six feet tall and dwarfs of only eighteen inches, cross-pollinating their blossoms in the same careful way. When the resulting peas were planted, they produced nothing but tall vines. But from the peas that these tall vines produced in the usual way grew both tall and short vines, and when counted they were discovered to be very nearly in the proportion of three tall vines to every short one. Similar results were obtained with vines that produced smooth peas and those that grew only wrinkled ones, with vines that bore colored blossoms and those that had white ones. A tabulation of Mendel's results with peas differing in these and in other characters is found in Table II.

Since in all these cases one of the characters in each pair seems to eclipse the other in the first hybrid generation (known as the F_1 genera-

tion), Mendel designated it as the dominant character, while the character that temporarily recedes from view he called the recessive. When, then, two plants are crossed differing in only one particular, the children manifest only the dominant character; but the grandchildren

TABLE II

Character	Number of Dominants	Number of Recessives	Ratio
Form of seed......	5,474 smooth	1,850 wrinkled	2.96:1
Color of seed coat .	6,022 yellow	2,001 green	3.01:1
Color of flowers ...	705 colored	224 white	3.15:1
Form of pods......	882 inflated	299 constricted	2.95:1
Color of unripe pod.	428 green	152 yellow	2.82:1
Position of flowers .	651 axial	207 terminal	3.14:1
Length of vine	787 tall	277 dwarf	2.84:1

Note that the greater the numbers involved in any experiment the closer the approximation to a ratio of 3:1.

(F_2 generation) are of the two types again and in the proportion of three dominants to one recessive. This does not mean that if, in the example first cited above, you should find four peas in a pod in the F_2 generation three would be yellow and one green, but it does mean that out of 4,000 peas of the second generation close on to 3,000 would be yellow and 1,000 green. Darbishire repeated

Mendel's experiment with the yellow-green cross, as have others, and obtained 105,145 yellow peas to 34,792 green in the F_2 generation, a proportion of 3.02 to 1.

When the recessive peas of the second generation (the grandchildren) are interbred, they are found to give nothing but recessives; green peas of this generation gave Mendel nothing but greens when planted generation after generation; short plants produced only shorts. A third of the dominants were found to give nothing but dominants, but the other two-thirds, when interbred, gave offspring that were again of the two types, dominant and recessive, and again in the proportion of 3 to 1. Using the letters D and R to stand for dominant and recessive, respectively, Mendel's law for the crossing of two plants or animals differing in only this one particular may be diagrammatically shown on opposite page. The plants of the F_1 generation (children) are designated D (R) rather than just D, although they show only the dominant character, because the recessive character shows up in the next genera-

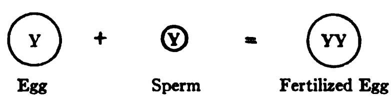
tion, so that Mendel conceived it must be present though hidden.

				D–R			
F_1 Generation				D(R)			
F_2	1 D			2 D(R)			1 R
F_3	D	1 D		2 D(R)		1 R	R
F_4	D	D	1 D	2 D(R)	1 R	R	R

But now what happened when plants were crossed differing in two characters? Mendel found, as before, that in the F_1 generation only the dominant characters were apparent, but that in the next generation the recessive characters reappeared. Thus pea plants bearing smooth yellow peas were crossed with those having wrinkled green seeds, and all the peas produced were smooth and yellow. When, now, these were planted and the flowers on the vines were allowed to pollinate freely in the natural way, there resulted peas of four sorts and always in a definite ratio, namely,

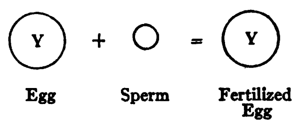
9 yellow smooth peas, 3 yellow wrinkled, 3 smooth green, and 1 green wrinkled. This proportion obtained only when large numbers were produced. These results of Mendel's have been repeatedly verified since.

Mendel could hardly have achieved such very definite results without devising some theory to account for them. He conceived that a pea plant producing yellow peas has something in its every cell that determines the color of the peas to be produced, even in the germ cells which fuse at the time of fertilization. Each character is determined by the presence of a definite substance that acts to produce it. When then the egg of a pea plant normally producing yellow peas is fertilized by the sperm (product of the growth of the pollen grain) of such a plant, the fusion in fertilization might be represented somewhat thus:

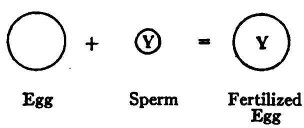


When a pea plant producing yellow peas is crossed with one producing green peas, Mendel

thought that the determiners for yellow were stronger than those for green, and so a plant which contained both would only produce yellow peas. The modern explanation is similar but simpler, namely, that if a determiner for yellow is present in the fertilized egg the plant that grows from this will produce yellow peas, but if no yellow determiner is present the plant will produce green peas. In other words, peas are naturally green, but may be yellow if a determiner for yellow is added. The case of a yellow-seeded plant fertilizing itself would be correctly represented above. In the case of a yellow-seeded plant crossed with a green-seeded we would have either



or



In either case the result is the same. The fertilized egg has in the cross a single dose of the

determiner while in the self-fertilized yellow-seeded plant diagrammed above it has a double dose; in both instances a yellow-seeded plant is the product, but one has all its cells provided with a single yellow determiner, the other has cells with two determiners.

Mendel further supposed that at one stage, when the cells of the plant divide to produce those cells known as the eggs and sperm that are so essential in reproduction, the determiners remain indivisible. It is evident that when a mother-cell divides to produce two daughter-cells that are to function as eggs or sperm, if the mother-cell has two determiners each egg or sperm may have one; if, however, the mother-cell has only one determiner, the sperm or eggs must be of two sorts, one with and one without the determiner. The pure yellow-seeded pea plant would have eggs and sperm each possessing a determiner for yellow (Y). The pea plant resulting from a cross of the yellow-seeded and the green-seeded would have eggs and sperm both with and without the yellow determiner and these two kinds in equal num-

bers. It is a matter of chance which sort of sperm will fertilize either sort of egg when these hybrid offspring shall produce their progeny. The possible combinations in such an event are portrayed in the following scheme:

Sperm	Y	○
Eggs Y	YY	Y
○	Y	○

The results are one fertilized egg with a double dose of the determiner, two that have a single dose, and one that has no yellow determiner. Now since the presence of the yellow determiner makes the plant yellow-seeded even if present in only a single dose we should expect the Mendelian ratio of three yellow-seeded plants to one green-seeded in the F_2 generation. It is also plain why the green-seeded plants only produce green-seeded offspring, for they have no yellow determiner in them. It is also

evident that one-third of the yellow peas of this generation will produce yellow-seeded plants only, for they have two determiners in the mother-cells that give rise to eggs and sperm, and so these will each have the yellow determiner.

The proportions of the resulting peas in a cross between a smooth yellow pea and one producing wrinkled green peas are obtained in a similar way. The plants of the F_1 generation are represented by SY, and both smooth and yellow are dominant characters. The sperm and eggs may (1) contain S and Y, (2) only S, (3) only Y, (4) neither S nor Y. The possible combinations are shown in the diagram on p. 43. Nine combinations contain both S and Y, three only S, three only Y, and one neither S nor Y. Therefore in the F_2 generation the proportion must be the Mendelian ratio, 9–3–3–1.

Mendel's law holds good with other forms, both animal and plant, quite as well as with peas. If, for instance, pure black guinea pigs are crossed with whites, the children are all black; the grandchildren are three-fourths of them black, one-fourth white. The whites

of this generation are pure recessives and only give white when interbred. One-third of the blacks are pure dominants and give when mated only black offspring; but the rest are

Sperm / Eggs	SY	S	Y	
SY	SSYY	SSY	SYY	SY
S	SSY	SS	SY	S
Y	SYY	SY	YY	Y
	SY	S	Y	

SSYY 1
SSYC 2
SYY 2
SY 4
SS 1
YY 1
2

hybrids and give again, when interbred, three black to one white. It does not follow that because white is a recessive in guinea pigs it will always be such. Thus if a white leghorn chicken is crossed with a black minorca the children are all white, the grandchildren three-fourths white, one-fourth black. In this case

SSYY 1
2
SSYC 1
SYYL
4
2

white is evidently dominant. Whether a given character will behave as dominant or not can only be told by trying it out by actual breeding.

Dominance may often be only partial, possibly it is never absolutely complete. The crossing of white and black Andalusian fowls is a case in point. The children, instead of being either black or white are black diluted with white, called by the chicken fancier a "blue." Of the grandchildren one-fourth are pure black, one-fourth pure white, and one-half "blue" hybrids. Similarly, when red and white four-o'clocks are crossed the children are all pink blossomed; neither red nor white is completely dominant. The grandchildren are one-fourth pure red, one-fourth pure white, and one-half pink.

QUESTIONS

1. What do you mean by heredity?

2. How did Mendel go about it in his work with peas to make sure of crossing two varieties so as to get a hybrid?

3. State Mendel's law as it applies to the offspring of the cross between smooth and wrinkled peas, carrying the matter as far as the great-grandchildren.

4. The hybrid peas will produce what sorts of egg and sperm, and what four possible combinations may there be in the fertilized eggs that will grow to new seeds?

5. Can you find other instances of the working of Mendel's law besides those given? Possibly you have raised pigeons or corn, and can give illustrations of some of the matters discussed from your own experience in crossing different varieties.

6. Will some members of the class undertake to try out a cross with some animals or plants so as to illustrate Mendel's law with actual materials which the class may see?

CHAPTER V

MAN A CREATOR

It is very evident from even so elementary a discussion of the matters involved in Mendel's law that at least some hereditary characters are pretty definite things which when once in a stock remain in it persistently. Yet by appropriate hybridizing of unlike stocks the groups of characters that have been united for generations may be shaken apart and reunited in new combinations. This possibility was recognized before the world generally knew of Mendel's law, but it was looked upon as a chance phenomenon; the successful breeder of race horses, for instance, was thought to be a good guesser, a skilful juggler, but it was scarcely deemed that there was any scientific basis for his procedure. The work of a few such breeders was so uniformly successful that it was undoubtedly founded on some of the fundamental conceptions of hereditary transmission, even if the

men themselves were not conscious of their scientific foundations. But with the recognition of the significance of Mendel's law, the breeder went to work to produce desirable modifications of existing animals and plants, so that they would more completely serve men's purposes. It seems worth while at the outset to get some clear notions of what has been done by breeders in their efforts to obtain new types of animals and plants, both by those who worked in the dark before the laws of heredity were at all known and those who are working now with better scientific foundations.

The origin of many domestic breeds and races, both of plants and animals, is obscure. We are not sure whether the dog is derived from one particular species of the wild dogs, like the wolf, or hyena, or if the several races that we know today are hybrids of several species of wild ancestors. The dog has been man's companion from earliest time. As soon as we find man's fossil bones along with his crude implements we find also the bones of the dog. He was domesticated so early that we

have no record of his real origin. While we think the chickens of today are probably derived from the jungle fowl of India, the many sorts of pigeons from the common rock pigeon, European cattle from the wild cattle that still inhabit some of the game preserves of England and Germany, yet it is a matter of probability, not of certainty.

Fortunately the incidents regarding the origin of certain breeds and varieties are known, and such are illuminating. In the first place many of the valued domesticated plants and animals have been transplanted from the wild quite recently. The turkey, for instance, is an American bird, the wild turkey still roaming the forests in some of the wilder sections. It has suffered little change apparently in the process of domestication. The same may be said of the duck (the common sort being an almost unmodified wild mallard), of some pheasants, and of the ruffed grouse, lately added to the list of domesticated animals. Recently the blueberry has passed under cultivation. The cultivated sort is much larger, juicier, and more

prolific than its wild parent form; yet the changes seem to have been induced merely by putting it under the more favorable environment in cultivation. The Concord grape achieved its present size and lusciousness at once on being brought into the garden from the wild. It is quite evident, then, that men may bring animals and plants under domestication either with or without producing marked changes in them. It is to be noted that after they are changed they revert to their wild condition again when returned to the state of nature.

In 1791 there was born on the place of a Massachusetts farmer named Seth Wright a queer-looking lamb with short bowlegs and a long sagging body like a dachshund. Now Seth Wright had been much annoyed by his sheep jumping pasture fences. With true Yankee insight he recognized the value of this bandy-legged lamb; it might become the progenitor of a breed that could not hurdle even a low fence, and high rail fences were built only with effort. To make a long story short,

Wright did produce a breed of sheep, the Ancons, by mating this ram to its own offspring, and so inbreeding for several generations. The Ancons were long a favorite breed, until replaced by sheep with much finer wool.

In 1889 there appeared suddenly in a herd of Hereford cattle at Atchison, Kansas, an animal without horns. This single animal was the founder of the race of polled Herefords. Among some orange seedlings brought to the United States by the Department of Agriculture from Bahia, Brazil, and planted in California, was one that when mature produced the peculiar seedless orange now commonly known as the navel. From this single tree cuttings have been taken to start others, and in this manner there have been derived from the one original tree all our orange trees that bear navels.

Note that the short-legged sheep did not arise by the selection of gradually shorter and shorter legged sheep, the hornless cattle by the gradual disappearance of the horns, or the navel orange by the slow elimination of seeds until the vanishing point was reached; but in

each case the new variety suddenly put in its appearance in its perfect condition. All the breeder had to do was to recognize the value of the new type.

The truck-garden region about Chicago is the greatest cabbage growing area in the world. Many of the farmers of northwestern Indiana, northern Illinois, and southern Wisconsin have devoted themselves exclusively to this one crop. Within a generation, however, the region has been invaded by a very serious disease, the "yellows," that attacks the young plant, withering and killing it. Fields that formerly produced tons of cabbages now yield absolutely none, and the virus seems to remain persistently in the soil even after other crops have been grown for several years. The plant pathologist of the University of Wisconsin was called in to help solve the trouble. The situation was studied for several years without avail. Then in the midst of a fifteen-acre field two lusty cabbage plants were found with well-formed heads, although all their companion plants had succumbed to the dread disease.

It seemed to the farmer a pitifully small crop, but to the expert a very hopeful one—two plants, at least, that were disease-resistant. Seed reared from these produced similar healthy cabbages on farms that had been unable to get a crop with the ordinary cabbage seed for years. And now with this new disease-resistant variety the region is returning with assurance to its very profitable industry.

Many other instances might be cited of the sudden appearance of new breeds of animals or new varieties of plants. Such have been long known and have been called "sports." Hugo de Vries, a Holland botanist, obtained seed of an evening primrose, at one time probably a native of Southwestern United States. He planted acres of this "weed" in his experimental garden near Amsterdam. He discovered that among thousands of plants which bred true to the original primrose, *Oenothera lamarckiana*, there also appeared plants so unlike as to be evidently new species, and these bred true. There was one with flowers double the size of those of the parent species. The

plants differed in other respects, too, but this was the most conspicuous dissimilarity: it was named *Oenothera gigas*. One had the veins of the leaves and the tips of the flower buds tinged deeply with red, and was named *O. rubrinervis*. These are but samples of the "sports" that were appearing under the very eyes of an expert scientist; de Vries gave to such forms the name of mutants and claimed that such mutations or saltations have been exceedingly important in the evolution of the higher types of animals and plants from their simpler predecessors. New types of plants and animals may appear, then, out of a clear sky, so to speak. These mutants breed true. The difference between them and the parent form may be great or relatively slight, but they unerringly perpetuate themselves.

No American has been more successful in producing new varieties of plants than has Luther Burbank. He has worked largely through the process of hybridization, achieving almost by intuition what the scientific breeder gets by careful study. Burbank undertook

to improve the florist's daisy. The common American daisy, a weed in many sections of the country, is exceedingly vigorous and is a free bloomer, but neither the squatty form of the plant nor the dirty white blossom cluster makes it particularly attractive. The English daisy has a blossom cluster that is much larger, and the plant is of fine upright habit, but it is rather delicate, demanding sheltered situations. The Japanese daisy has small flower clusters, but these are of a wondrous pearly luster. Burbank conceived the project of combining the hardihood and free-blooming quality of the American species, the fine habit and large size of the blossom cluster of the English species, and the luster of the Japanese. He cross-pollinated two of these and then bred the hybrid plants with the third species and succeeded in achieving the desired combination. The new daisy he called the Shasta daisy.

Burbank's potato, produced early in his career and sold to an eastern seed man for one hundred and twenty-five dollars, is estimated by the United States Department of

Agriculture to be adding to the wealth of the nation by its increased productivity some seventeen millions of dollars annually. These are but a few instances of his many successes.

Burbank hybridizes by wholesale rather than by wise forethought and takes his chances on getting the hoped-for union of characters. His skill seems to consist in judging what seedling plants in thousands have the combination of desired characteristics in such form that their progeny will perpetuate them. Such a method frequently entails the destruction of acres of hybrids that do not manifest a valuable reunion of features. Burbank's remarkable knack of achievement has been duplicated by other experimenters who are more scientific in their methods and strictly dependent on the advance made in our knowledge of the law of heredity.

A few years ago the prairie lands of the Canadian Northwest territories were thrown open to settlers. It was soon discovered that these fertile lands were capable of producing enormous wheat crops, quite equal to those

that made such states as the Dakotas famous. There followed a great exodus of American farmers, from the border states particularly, into these promising lands. Within a few years, however, most of these adventurers came back to the States, for the early frosts of the new territory often nipped the unripe grain and spoiled the harvest. Not infrequently, too, the heavy gales common on these northern prairie lands blew down the grain in late summer, before it was ripe, making it well-nigh impossible to harvest it. Canadian farmers sent to the scientific breeders an insistent demand for a new type of wheat, one with the desirable hardness (the American miller likes no other), with the large yield of the prolific brands, but also one that would ripen early and that should have an exceptionally strong stalk to stand up against heavy winds. These qualities were all known, but in no one wheat. Thus Red Fife, a Russian wheat coming to America by way of Germany and Scotland, is hard and a high yielder. An Indian variety possesses the short sturdy stems, though it is

late. But the breeders went to work by a process of hybridization and selection, based on Mendel's law, to unite the needed qualities in one variety, and they succeeded so well that in three years' time they could begin to send the farmers small amounts of seed that met the requirements. Now these great prairie provinces are producing regular and dependable crops.

It was long taken for granted that improvement could be effected in a herd of animals or a plant crop by selecting from the general run of individuals the best ones to use for continued propagation. Thus the farmer went through his field at harvest time and picked out the largest heads of grain and those with the heaviest kernels to use as seed for the ensuing year, hoping that this process, repeated year after year, would increase the yield of his land. The chicken fancier selected the hens that produced the largest number of eggs to use as breeders, in the hope that the egg production of the flock would gradually rise. But this sort of mass breeding was found to yield very unsatisfactory results. Galton had discovered

years before that the children of two very tall individuals are not likely to be as tall as the parents; the same tendency to return to mediocrity is seen in the children of very short parents. Johannsen found similarly that if you plant large beans in a garden where cross-pollination is certain, the offspring are prone to be of less size on the average, but if you plant a single large bean and let the blossoms on this plant self-fertilize, the beans so produced are very like the parent in size. That is, pure-line stock is true to its type. Nilsson, the famous director of the Swedish Experimental Station at Svalöv, found that the wheat produced by planting the kernels of a single head was remarkably uniform, displaying only the parental qualities; but if seed from a number of heads, all equally good to the eye, were sown in the experimental plot, the resulting grain was not at all uniform. Some might be good, much indifferent, and some really bad. Nilsson conceives that such grains as our oats and wheat are resultants of the blending of many strains, and that these separate out constantly, appear-

ing more or less pure on individual plants. An ordinary crop is therefore an assemblage of many varieties. Only as you succeed in producing seed of a single variety will the crop raised be uniform or dependable. He therefore undertook to establish a number of these pure-line or pedigree cultures and find out by experimental planting in various locations which one was best adapted to yield large crops in a particular soil and particular climate. So he has been able to furnish the farmers of Sweden, working under the very diverse conditions that exist there, the particular types of wheat or oats that best fit their needs. Often it is necessary to hybridize two or more varieties and establish the right combination of desirable qualities by selection, but this is a relatively simple matter when pedigree cultures are at hand, each breeding true to one or more of the characters needed.

Our cultivated wheat was derived from a wild plant similar to, if not identical with, one discovered recently growing like grass in the rock crevices and sparse soil of the rougher

portions of Palestine. Strangely enough our European strains of wheat will not stand these very conditions of drought that maintain so commonly in the semiarid region where the wild progenitor thrives. Apparently man has selected it through these many ages for maximum yield under the most favored conditions of soil and moisture, so that its hardihood has disappeared. It is now a pampered weakling. We lose half our cereal crop by drought. It is hoped that some of the sturdiness of the original stock may be bred into modern strains of wheat by hybridization, so there may be produced a wheat of high productivity that will grow even in arid regions. It would add enormously to the value of some of our western lands where the rainfall is slight if such a crop could be assured. The Indians of the Southwest have achieved such a result with corn, and the corn of the desert tribes is a marvel of adaptation, a dwarf plant with small leaf surface but a large area of shallow roots to absorb the dew and light showers, and a single ear that is very large, considering the size of the plant.

No less remarkable is the variety of types of corn that civilized man has produced to suit his needs. If corn is raised for the purpose of manufacturing cornstarch, a variety that has a high percentage of starch is sown; if it is to be fed to beef cattle, it must be a sort that is rich in protein; if hogs are to be fattened, the oil content must needs be large; if it is to be used as a table vegetable, it must possess a large percentage of sugar. No sooner is a new use discovered for corn than the breeder develops a variety to suit it. Then, too, the yield per acre has been enormously increased, in part by better methods of cultivation, but in part also by improving the type of corn plant. The ideal plant is one with a strong, well-buttressed stalk, with two large ears, that will stand up even in heavy winds; it must possess broad yet firm leaves, for the manufacture of the materials that go into the grain occurs in the leaf. The ears should be long and thick without too large a cob, the latter well covered even over the tip and butt with straight rows of long even kernels that fit together without waste spaces (Fig. 5).

A single ear of such seed corn has sold for hundreds of dollars.

It must be recalled that at the top of the corn stalk there appears what is usually called the

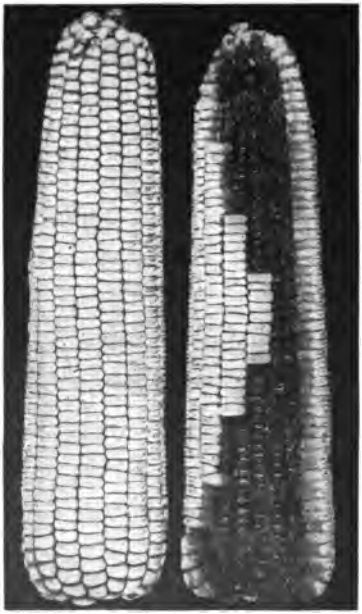


FIG. 5.—A good ear of corn. Note the close-fitting kernels

"tassel," really a cluster of blossoms that bear only stamens. Such separation of the stamens and pistils on different blossoms is quite common in plants that depend on the wind to

carry their pollen; grasses, sedges, and many trees like the willows and poplars are familiar examples. There protrudes from the young ear the bunch of silk, each thread of which is a style, its tip a stigma of one pistil. The ovary contains one ovule and after fertilization it develops into a single kernel of corn; there are as many pistils and of course as many silks as there are kernels in the ear. If two or more kinds of corn are planted in the garden and these tassel out at the same time, the kernels in the ears may be in part or entirely hybrids. When Mexican black corn and ordinary varieties are planted together, some kernels on the ear will be black, some white, depending on whether they are hybrids or not.

Since it has been found impossible as yet to get any one corn that has all the desired qualities in it and that breeds true, the farmer often has recourse to planting in alternate rows two varieties, each with some of the desirable qualities, so that they will cross-pollinate and the resulting hybrid kernels, it is hoped, will have most of the desired qualities.

In recent experiments conducted at various state experiment stations to produce strains of chickens with increased egg-laying ability, it has been found that it is not only necessary to select as a breeder a hen that lays well, but that her offspring must be good layers too. In other words, the breeder must have proof that the animal has the power to transmit her desirable quality or, as he says, is prepotent. It is by close inbreeding with such stock that the two-hundred-egg-a-year hen has been developed.

SUMMARY

The breeder hopes to discover animals and plants in the wild state that may serve mankind well when domesticated, and he expects that some at least will be improved merely by domestication. He is on the lookout for sports or mutants that show valuable new characters; these he adopts and conserves. He makes new combinations by hybridization and watches for complex varieties to separate into their component strains so as to start valuable pedigree

cultures. By close inbreeding he prevents the dilution of valuable traits.

QUESTIONS

1. Can you see any reasons why it is likely that the dog is the result of crossing several different species of wild ancestors rather than being the derivative of only one of them? Can you think of any other domesticated animals other than those given that are little changed by man's adoption?

2. It is quite possible to find in the literature many illustrations of domestic breeds arising as sports; will you add to the few given?

3. Are there disease-resisting plants other than the cabbage; can you find out how they arose? Are there disease-resisting races of men?

4. What was Hugo de Vries's contribution to our discussion of heredity?

5. Will someone look up and report the way Burbank produced his plum cot, stoneless prune, and royal walnut?

6. Do the farmers or gardeners in your vicinity practice mass breeding or pure-line breeding?

7. Will you estimate the value of the work of Nilsson of the Swedish Experiment Station?

CHAPTER VI

THE VISIBLE BASIS OF HEREDITY

As we have seen in a preceding chapter, when the eggs of the frog are shed into the water by the female, the male at the same time discharges the sperm on to them. The pair of frogs then pay no more attention to their eggs. Such fertilized eggs have no connection with the bodies of their parents, so that whatever hereditary characters are displayed by the young frogs must evidently be transmitted entirely through the eggs and sperm. A similar situation obtains among many of the lower plants and a majority of animals; the egg develops entirely dissociated from the parent. While in the higher animals the egg, during its development, is held in one of the reproductive organs of the mother (the womb or uterus), the connection of the growing embryo with the parent is not as close as at first appears; no blood flows from the parent

to the young, nor is there any nerve connection between the two. It is no wonder, then, that the prying eye of the microscope has been turned upon these reproductive cells, the eggs and sperm, to see if there can be discovered in them anything that may be regarded as the carriers of the hereditary characters. Certain structures have been discovered which many scientists believe do constitute a visible physical basis of heredity.

The term "cell" applied to the egg is rather unfortunate, for it calls up a vision of an empty space surrounded by walls. The cells that make up the animal and plant are, on the contrary, masses of protoplasm, each usually bounded by a layer of substance, the cell wall, that is formed by the protoplasm; within each cell is a small dense mass of protoplasmic material, the nucleus, that is quite essential.

Protoplasm is a somewhat jelly-like material, almost transparent, sensitive, contractile, capable of taking in and using certain food substances to build new protoplasm. The term is a collective term, somewhat as "society"

is; it stands, not for a single substance, but for a group of related substances. It is the physical basis of life, that in which life inheres; the living part of animal or plant is always protoplasm. It is by no means invariable; quite the contrary, it probably has a different composition for each species of animal or plant, perhaps for each kind of tissue. The protoplasm of the cell is differentiated and its parts serve a variety of purposes. The nucleus functions differently from the cell body; the chloroplasts of the plant cell that give it the green color serve to make the sun's energy available for the manufacture of plant foods. Various foreign substances may be held in the protoplasm and at times be almost indistinguishable from it; such are the food materials in process of elaboration or the waste matters that are on the way to excretion.

After fertilization, it will be remembered, the egg cell proceeds to divide and subdivide, forming a mass of cells that gradually transforms into the embryo and that finally grows, by continued cell division and differentiation, into the

adult (Plate II, p. 26). Cell division at times may be a very simple process. The nucleus elongates, becomes dumb-bell shaped, and pinches apart to form two new nuclei. The cell body goes through a similar performance, and each new nucleus lies in one of the new cells. But in most cases cell division is much more complicated. The physical condition of the cell protoplasm varies much; at times it is fluid, again gelatinous, and it may assume a fibrous or spongy structure with fluid materials in the meshes or spaces. As the nucleus prepares for division its substance assumes this latter condition. At the points of juncture of the fibrous strands there are found granules that stain very deeply with certain chemical substances; this deeply staining material has hence been called chromatin. As the early division stages come on in the cell the spongy network becomes coarser and the chromatin granules unite to form larger grains (Fig. 6, B and C). Many strands of the fibrous mesh break, others appear to contract and draw the grains of chromatin closer together until finally this nuclear material

appears as a number of rodlike, ovoid, or other characteristically shaped bodies now known as chromosomes. Meanwhile the boundary of the nucleus has disappeared and the chromosomes have come to lie in one plane in the mid-region of the more or less spherical cell, designated the equatorial region (Fig. 6, F). Now each of the chromosomes divides into equivalent parts. Not infrequently the division begins before the component chromatin grains fuse, and then it is apparent that each tiny granule divides so that each daughter chromosome receives one-half (Fig. 6, E). The daughter chromosomes move toward the opposite poles of the cell and fuse (Fig. 6, G and H). This solid mass gradually becomes porous as the meshwork reappears. New nuclear walls are formed. Between the two new nuclei the cell lays down a new cell wall and what was one cell has thus become two (Fig. 6, I).

The whole process impresses one as a device for insuring the equal distribution of the chromatin materials to the daughter-cells. If this chromatin is the real bearer of hereditary

qualities, its equal partition is significant, for each cell must have its share of the fundamental

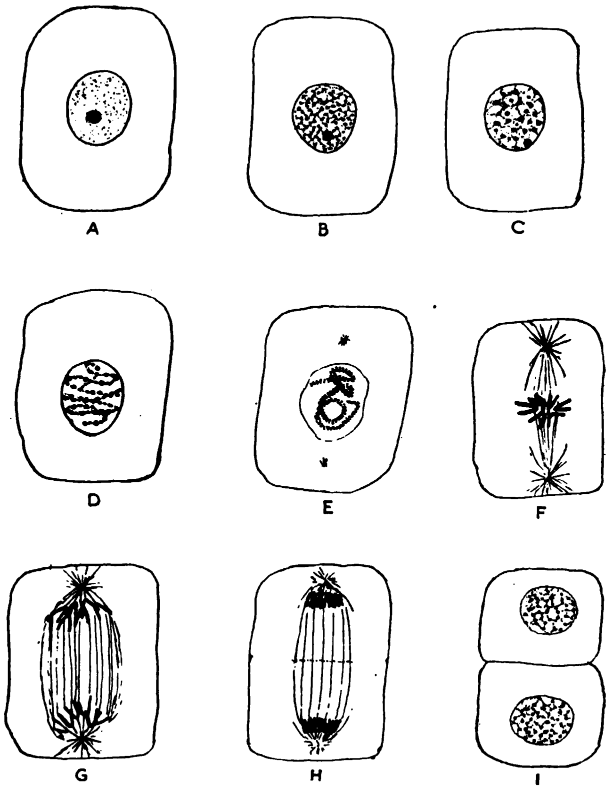


FIG. 6.—A cell dividing, showing behavior of chromosomes

substance peculiar to the plant or animal. Such a precise method for dividing the chromatin is

one weighty reason for believing that it is the physical basis of hereditary transmission; other reasons follow. The sperm consists of a head made almost exclusively of chromatin, and of a middle piece, and tail that propels the sperm to the egg. These parts are often dropped at time of fertilization, so that only the head unites with the egg. Yet the plant or animal resulting from the fertilized egg may show quite as many hereditary traits derived from the father's ancestry as from the mother's; these evidently must have been brought into the egg by the chromatin. Boveri was able to shake the nucleus out of certain large sea-urchin eggs and then fertilize these denucleated eggs with the sperm of another species. When these eggs developed they showed the specific characters of the latter only; none of the characteristics of the species from which the eggs were derived were apparent. He also found that under exceptional conditions, when sea-urchin eggs were fertilized with sperm of the same species, two or even more sperms would enter the same egg. Then the chromosomes are distributed

to the cells as they form, in a very erratic manner, and the resulting embryos are highly abnormal, presumably because the hereditary determiners have gone astray.

The cells of any species of animals or plants always contain a specific and constant number of chromosomes except as noted below. The number may vary greatly in different animals and plants; thus a biologically famous little fruit fly (p. 81) has four, the mosquito, *Culex*, has six, the rat sixteen, the frog twenty-four, and a white man forty-seven. In radiolarians it is claimed the number is about 1,600. There is a similar wide variation in the number of chromosomes found in plant cells. There is no connection between the number of chromosomes and intimacy of relationship; animals widely separated in the animal kingdom may have the same number; those very closely related may have an unlike number.

It is very evident that if the egg of an animal contained the regular number of chromosomes and the sperm brought in as many more at time of fertilization, the new animal developed from

the fertilized egg would have twice as many chromosomes as either parent. This doubling process would continue generation after generation and soon give us an incalculable number. During the production of the eggs and sperm from the germ mother-cells in most animals, and in the production of the spores from the spore mother-cells in plants, there is one division when, instead of the usual number of chromosomes appearing in the equatorial plate (Fig. 7, F), only half that number appears, but these are apparently double chromosomes. When they divide to form the new nuclei, the chromosomes that form the doublets go to separate cells. By this "reduction" division in place of the customary "equation" division the daughter-cells have unlike chromatin material. Thus if we number the chromosomes 1, 2, 3, 4, then the equation division would give to each daughter-cell one-half of each; but the reduction division might give to one daughter-cell any two, as 1 and 3, and to the other daughter-cell the others, 2 and 4. When the egg and sperm come together in fertilization,

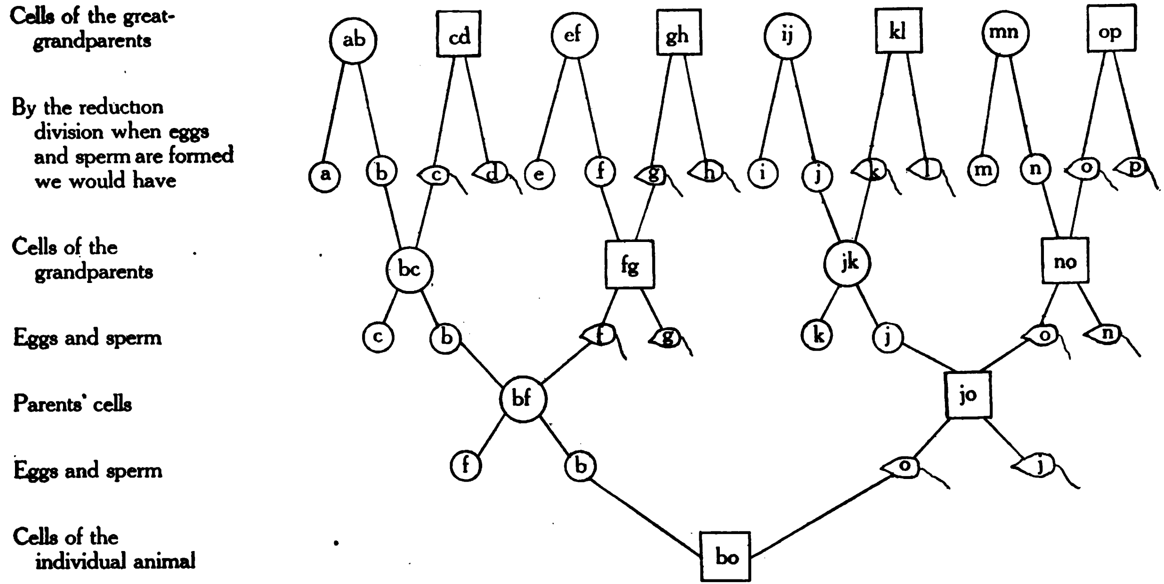
the half-number (haploid number) in each unite and make up the usual (diploid) number once more. This takes place in animals usually very soon after the reduction division has occurred; but in plants the union may be long delayed, for the spore does not at once produce the germ cells, but the sporophyte, whose tissue then consists of cells with the haploid number of chromosomes.

There is very good evidence that even when these chromosomes seem to lose their identity in the newly formed nuclei they really do not. When, for instance, two animals of similar but still unlike species, such as different sorts of minnows, are used as parents, the chromosomes in the germ cells are of such different shapes that they can be recognized in the equatorial-plate stage of the successive divisions of the fertilized egg and even in the divisions of tissue cells in the well-developed young fish. In some plant cells the swollen and alveolar chromosomes can be distinguished apparently even in cells that are in the resting stages. Biologists are inclined to believe that chromosomes retain their identity,

although in many cases we as yet have no visible demonstration that such is the case.

If we letter the chromosomes in the ancestors of an individual so we can keep track, generation after generation, of certain ones, we might have some such scheme as the following to represent the source of the chromosomes in the individual. For the sake of simplicity it is assumed that in the particular animal considered there are only two chromosomes in the body cells. The squares and large circles represent the individual animals, male and female, respectively; eggs and sperm are represented by conventional small circles and tailed figures. The cells of the individual animal, one of which is represented in the lower row of the diagram, were derived from the fertilized egg by its repeated cleavage. This cell, as all of its fellows, contains two chromosomes designated *b* and *o; b* comes from the egg, *o* from the sperm, which of course were derived from the mother and father, respectively. Similarly, the mother's cells with chromosomes *b* and *f* were derived from a fertilized egg, the unfertilized egg contributing

IDENTITY OF CHROMOSOMES



the chromosome *b*, the sperm *f*. Tracing back the source of the chromosomes thus step by step, it is evident that the two chromosomes in the cells of this particular individual whose ancestry is diagrammed were derived one from a great-grandmother, one from a great-grandfather, and they might in a similar way be traced back much farther. If now a given chromosome contains a set of determiners for particular characters we can readily see why this individual bears striking resemblance to two of its great-grandparents. This, of course, is a crude illustration of the sort of thing that inheres in the notion of the individuality of the chromosomes. It must not be taken for granted that all of this has been proven; it is merely a working hypothesis rendered probable by recent investigations and the experience of breeders.

The first successful attempt to connect specific characters with particular chromosomes came with the discovery that in certain insects there is one chromosome in the male called the odd or *x*-chromosome which does not pair with

a fellow preparatory to the reduction division at the time the sperm are formed. It goes entire to one or the other of the sperm so that these are of two sorts, one with the odd chromosome, one without it. It was Henking who made this discovery in 1899 in a locust or grasshopper, *Phyrocorrus;* it was soon confirmed by other investigators working on other animals. McClung, the same year, suggested that this odd chromosome is a sex-determiner. If an egg is fertilized by a sperm that contains the odd chromosome, the fertilized egg develops into a female, but if fertilized by a sperm of the other type it develops into a male. Thus in the white man there are forty-seven chromosomes in the male, but forty-eight in the body cells of the female. Evidently the chromosome which is an odd one in the male finds a mate in the cells of the female since the chromosome number is even. The female may be said to have a double dose of the sex chromosome, the male a single dose. Representing the haploid number of chromosomes by n the formula for the cells of a female is usually given as $2n+2$, for the

male $2n+1$. Each egg would have $n+1$ chromosomes. The sperm will be of two sorts, those containing n chromosomes and those having $n+1$. If an egg is fertilized by the latter sort of sperm it will produce a female $(2n+2)$; if by the former a male $(2n+1)$. Since the chances are equal that a sperm of one sort will find eggs to fertilize as often as will those of the other type, the number of males ordinarily equals the number of females. In some animals in which one sex greatly outnumbers the other it has been shown that there is a very high mortality among the sperm of one type.

Biologists are not agreed that the odd chromosome is really the sex-determiner; it may merely be a sex-indicator. But at any rate there is established a specific relation between a very conspicuous character, sex, and the presence of a particular chromosome (or, at times, group of chromosomes). This relation has been found to obtain in a very great variety of animals. Recent work tends to show that the original impulse toward one or the

other sex due to the presence of the sex chromosomes is only one factor in the final outcome, though it is probably the most important.

Professor Morgan, of Columbia University, who has for many years been conducting experiments on inheritance in the fruit fly, *Drosophila*, finds that the hereditary characters behave as if they were bound together in four groups—one large group, one with very few characters in it, and two that are intermediate. Now *Drosophila* has four chromosomes in its cells—one very large one, one quite small, and two of intermediate size. Dr. Morgan thinks that this is more than a coincidence. His work tends to show, not only that a specific character is located in a particular chromosome, but that the determiner for the character is located at a particular spot in the chromosome.

It must be apparent that the hereditary characters of an individual animal or plant are determined at the time of fertilization of the egg from which it comes. If this be so, the common belief that prenatal influences produce heritable characters must evidently be false. Farmers

used to hang a red blanket in the stall of a cow, some weeks before a calf was expected, as a measure to insure a solid red color in the offspring, as that was very desirable in certain breeds. Such a performance is quite useless. Jacob believed in accordance with the prevalent notion of his day that he increased the number of streaked and spotted cattle by a similar process, but the facts related (see Gen., chap. 30) are quite as well explicable on the assumption that Laban's herds and flocks were hybrid stock. Birthmarks are sometimes thought to result from something the mother sees or longs for during the prenatal life of the child. Undoubtedly they are not so produced, and the resemblance of a birthmark to some object seen or desired is all a matter of chance. Hundreds of mothers go through similar experiences without the child exhibiting any birthmark. Indeed it is quite impossible to conceive how any effect could be produced on the developing child, for there is no nerve connection and no direct blood flow between mother and baby.

It is very evident in the foregoing diagram that any two chromosomes other than *b* and *o* might have found their way to the individual from the grandparents. What combination of chromosomes will finally arrive in any individual is a matter of chance. Remember that there are forty-eight chromosomes in the human cells of the white woman (forty-seven in the man), and it is apparent that almost an endless number of combinations are possible. Half of them in any child come from the mother, half from the father, but which ones of the forty-eight of the mother will make up the twenty-four that go to the child, or which of the father's will be contributed as his share, chance only determines; so the probability is that no two children of a family have the same combination of parental chromosomes, unless it be identical twins, which come from the separation of the fertilized egg at the two-cell stage, each cell producing one child. This very process of sexual reproduction seems to be an excellent means of producing endless variations in the offspring. If one had forty-eight dice in a

box and were to shake out twenty-four, there is little likelihood that in a lifetime he would twice shake out the very same twenty-four.

The plant breeder recognizes this fact and propagates his stock by cuttings rather than by the sexual process wherever possible. If a tree is grown from an apple seed the fruit produced is seldom as good as that on the original tree, because when the chromosomes recombine in the sexual process the chances are that so efficient a combination will not again arise. So the grower takes a twig from his tree and plants it so as to get a new tree whose cells possess the same chromosome content as the original. It is only in the sexual process that reduction and recombination of chromosomes occur, and these are the basis of hereditary characters. When, however, he is after new things, better types of fruits or grains, then the breeder not only makes the plants reproduce sexually, but he uses as parent forms plants that have unlike but desirable characteristics, in the hope that some new combination may result that will be better than either of the parents.

QUESTIONS

1. Have you seen cells under the microscope? You can see them with the naked eye in some vegetable tissues, when they are much swollen with sap, as in the pulp of watermelon, or in the coarse tissue of the water-lily leaf or elder pith. Will some member of the class supply some such material? Such cells have largely lost their living protoplasm.

2. In cell division what is the customary behavior of the chromosomes?

3. Why is a reduction in the number of chromosomes necessary when the plant or animal reproduces by eggs?

4. What primarily determines the sex of an animal?

5. What is the evidence against birthmarks?

6. Why does the fruit-grower propagate by cuttings rather than by seed?

CHAPTER VII

SOME APPARENT EXCEPTIONS

Many of the cases of inheritance that at first appeared to be exceptions to Mendel's law are found to be explicable by it, and really strengthen our belief in its accuracy and universality. Thus several years ago Bateson, one of the foremost English investigators, crossed two sweet pea plants that bore white blossoms. Strangely enough, the offspring were plants that had purple blossoms. The plants reared from the seed of these purple-flowered kinds were part purple, part white, in the proportion of 9 to 7. Bateson recognized in this the familiar Mendelian ratio of 9–3–3–1, though the last three terms have united to produce the 7. The normal Mendelian ratio indicates that at least two factors are involved, and Bateson conceived that the purple character is really dependent upon two factors, and that both must be present to produce it. One of the

parent white peas evidently contained one factor, the other white parent had the other factor in it, and when the two came together the resulting pea plants produced purple blossoms. Of the offspring of the purple blossom peas 9 contain both factors and are therefore purple, 3 contain one factor, 3 the other, 1 neither, and all these are white.

The original wild sweet pea is purple-flowered. The factors for purple have, in the course of cultivation, been separated. The white peas in the experiment each contain one, hence the original purple reappears, a phenomenon known as reversion—the reappearance of primitive ancestral traits in the offspring of more highly developed animals or plants. Many colts exhibit when very young more or less of the zebra-like striping characteristic of the original horse. Human beings are sometimes born with a harelip or a clubfoot, conditions that are permanent in the lower monkey-like types of mammals; it is easier to bite with the front teeth when the lips can be drawn out of the way,

and turned-in soles of the feet facilitate climbing.

So many cases similar to that of the peas mentioned above have been found that it is now recognized as unusual to find a character dependent on only one factor. So the factorial hypothesis has come into vogue: this means that characters as such are not heritable things but that there are certain factors that are really the heritable units and their interplay causes the appearance of a particular character. The manifest character in the case given is the purple color of the blossom. What the factors really are we do not know, but we do believe they are heritable units and that together they produce the visible color. Occasionally one factor may be the sole cause of the character; then, of course, the latter acts as the heritable unit. Usually a character is the resultant of the interplay of several factors. Sometimes one factor is instrumental in determining several characters. At times two or more factors may independently produce like results. Some concrete illustrations

of these several possibilities will make them clearer.

When several factors enter into the production of one character, the phenomena of its inheritance are often apparently very complicated. Thus coat color in rabbits is due to the interaction of seven separable factors, three of which have to do with the production of color, three with its distribution, and one with its intensity. Possibly the factors are chemical substances whose reactions produce the apparent effects on the coat color. That is mere hypothesis; since we cannot tell just what they are, they are designated by letters. The color factor, C, must be present to have any color at all. If absent, the rabbit is white, an albino. B is the factor which acts on C to produce black, Y, a factor which acts on C to produce yellow. The yellow is obscured by the black which overlays it if the factor B is present. E is an extension factor, acting on black pigment to spread it over the entire body. If this factor is absent, only the eyes and the skin of the feet are pigmented. U is called the uniformity

factor, which if present determines that the color shall be uniformly spread over the surface. If U is absent the color appears in blotches, separated by white areas. A designates the agouti factor. When this factor is present the color is distributed in a particular way in each hair: the tip is black, then follows a band of yellow, and the base of the hair is gray. The general effect produced is a uniformly gray coat color. I stands for the intensity factor, which if present makes the black or yellow strong. If absent, the black is a diluted black or blue, and the yellow becomes cream. If factors A, B, C, E, U, are present in the cells of an individual, it is a gray, for the agouti hair pattern can develop if C is present with factor B to operate on it. E determines that the color is distributed all over the body, and U that it is uniform, not interrupted by white patches. But an individual whose cells contain A, B, Y, C, E, U, would also be gray, as would one whose cells contain A, B, C, E, U, I, or A, B, Y, C, E, U, I. Some or all of these factors may be present in double dose, so that AA, B, C, E, U;

AA, BB, C, E, U, etc., are all formulae for the factors present in gray rabbits. In fact, there may be thirty-two all-over gray rabbits that differ in the complex of factors present in their body cells. They appear similar, and are therefore said to be *phenotypically* alike; but they all may give unlike progeny, since their germ cells, eggs and sperm, will contain unlike assortments of factors, and they are therefore called *genotypically* unlike.

If we are crossing two individuals that differ in one factor (or one character, if that character is determined by a single factor), the ratio of individuals in the F_2 generations is 3 to 1, in which 3 possess the factor in question, one does not. Of the three, one has it in double dose, two in single dose. There are two phenotypes in this case, i.e., two differently appearing animals or plants, and three genotypes. If two factors are involved, the proportion is 9–3–3–1, that is $(3+1)^2$. A reference to the checkerboard (p. 43) showing possible combinations in the F^2 generation in this case shows there are four phenotypes (2^2) and nine genotypes (3^2).

In the same way when two individuals are crossed differing in three factors, the proportion in the F_2 generation is 27–9–9–9–3–3–3–1 $(3+1)^3$, and there are eight phenotypes (2^3) and twenty-seven genotypes (3^3). When seven factors are involved, the proportion obtaining in the different sorts of offspring in the F_2 generation is $(3+1)^7$, and there are 128 phenotypes (2^7) and 2,187 genotypes (3^7). So that if one were to mate the albino rabbit with the factors BB, EE, UU, II, AA, in its cells (no factor C is present, so it is colorless) with the cream mottled white whose cells have YY, CC, the offspring will be gray. If these grays are mated, 128 different sorts of rabbits, as far as appearances go, might appear in the offspring, and there would be possible more than 2,000 combinations of factors in their cells. This illustration makes apparent the almost limitless complexities involved in tracing the inheritance of any character dependent on the interplay of several factors.

The following case will illustrate the presence of two factors, either of which may cause the

character. It was found at the Swedish Experiment Station at Svalöv, previously mentioned, that when two wheat plants were crossed, one of which had kernels that were brown coated, the other white coated, the expected Mendelian ratio of 3 to 1 in the F_2 generation did not appear, but the brown-coated kernels were fifteen times as numerous as the white-coated, and were of several shades of brown. The ratio 15 to 1 evidently suggests that two factors are involved, but the customary grouping 9–3–3–1 is changed, so that the first three terms are united in a single term. Nilsson, Director of the Swedish Station, supposes that there are two factors present, either of which produces brown (see checkerboard). Both are present in double dose in the offspring in the F_2 generation, in one case out of the 16, and the brown color is very deep. One is present in double dose, the other in single dose in 4 cases, and the brown color is less pronounced. Only one is present either in double dose or single dose in 6 cases, and the brown color is still paler. Neither is present in one case, the white. In another

wheat the coat color is red. When crossed with the white-coated wheat the proportion of F_2 offspring is 62 red of varied shades and 1 white. Evidently there are three factors

Eggs / Sperm	Bb	B	b	
Bb	BBbb	BBb	Bbb	Bb
B	BBb	BB	Bb	B
b	Bbb	Bb	bb	b
	Bb	B	b	

producing red in this case, and the possible shades of red are very numerous in this F_2 generation.

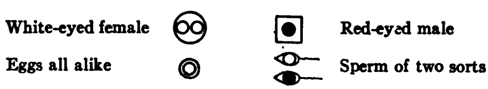
Davenport believes that his study of crosses between whites and negroes shows with a fair degree of probability that the full-blooded African negro has two factors for black in his

skin, besides factors for red and yellow. The white individual has the same pigments present in the skin but in different proportions. The skin of a tanned brunette appears on microscopic examination identical with that of the negro. There are of course other distinctive negro features, like the crinkly hair and broad nose. The two black factors may be designated A and B, and they are present in double dose, so that the chromosomes of a negro would contain AA, BB. The germ cells after reduction must then contain factors A and B. The mulatto (cross of the black and white) would have the same two factors in the body cells both brought in at fertilization by the negro sex cell, while the corresponding white sex cell would contain neither factor. Egg or sperm of a mulatto may therefore conceivably contain A and B, A, B, or neither. The possible resulting combinations when the egg is fertilized by a sperm are (construct the checkerboard) 1 AA BB, a full-blooded negro; 2 AA B; 2 A BB; 4 A B; 1 AA; 1 BB; 2 A; 2 B; and one neither A nor B, the latter a pure white.

The several combinations in this list between that of the full-blooded negro and the pure white make possible several shades of dark pigmentation. What appears as a blend of black and white resulting in a dilute black is really the inheritance of one or more of these black determiners, thus producing the several possible intermediate shades.

Little is known as yet concerning the behavior of the other negro characteristics in inheritance. They apparently are largely independent of each other and of skin color, so that in crosses with whites the broad nose, the thick lips, or the long arms may any or all appear in a very light individual, while a dark-skinned individual may have the features of the white. Negro blood is not necessarily an index of mental inferiority. W. E. Burghardt DuBois, author, professor of economics at Atlanta University, an acknowledged leader in southern problems, and Paul Laurence Dunbar, American poet, are samples of the continually recurrent intellectual ability in individuals of pure negro extraction.

Another apparent exception to Mendel's law is the inheritance of sex-linked characters, but it also is explicable on the supposition that the factor or factors that determine the character are contained in the sex chromosome. In fruit flies, reared in Professor Morgan's laboratory, there appeared a sport with white eyes. The normal fly has red eyes. The factor for red in the eye, it is supposed, is carried by the sex chromosome. We may represent the sex chromosome by ● and show the presence of the red factor by making it black, its absence by leaving it uncolored, ○. Since the female has a double dose of the sex chromosome, the male a single dose, a cross of the red-eyed male and the white-eyed female would be represented thus:



The offspring in the F_1 generation would be of two sorts, ; the left-hand diagram representing the red-eyed females, the right-hand the white-eyed males. There will be equal

numbers of each, since the chances are equal that the egg will be fertilized by either sort of sperm. The expected Mendelian phenomenon does not appear, for we should anticipate that in crossing a red-eyed with a white-eyed, the F_1 generation would be all either red or white, depending on which character is dominant. But if we make the supposition suggested, viz., that the factor for red eye is carried by the sex chromosome, the facts found are adequately explained by the hypothesis, and this does no violence to Mendel's law. It is merely an extension of it.

There is one form of color blindness in human beings that is customarily confined to men. Still, the daughter of such a color-blind father, though herself normal, may transmit the difficulty to some of her sons. If we suppose that the factor for the perception of color is carried in a sex chromosome, color-blind men would be represented thus, $\boxed{\circ}$; and the normal female so, (●●). The eggs from the female will be all of one type, ◉; the sperm from the male of two sorts, one with the sex chromo-

some, which, however, does not carry the factor for perception of color, ⊸, the other without the sex chromosome. The egg may be fertilized by either of these two types of sperm, and the results will be either, first, females that perceive color, ◐; or, secondly, males that perceive color, ▣. The color blindness seems to skip this generation. If now this woman mates with a normal man, the eggs may be of two sorts, those containing the sex chromosome that carries the factor for the perception of color, ◉; or those with the sex chromosome that does not carry the factor for perception of color, ◎. The sperm from the normal father will be of two sorts, those that carry the sex chromosome containing the factor for perception of color, and those that have no sex chromosome. Either sort of egg may be fertilized by either sort of sperm, so that we may get in the next generation, first, normal daughters, ●; secondly, daughters like their mother, ◐; and color-blind males, ▢. In the same way it is evident that if a woman like the one just considered were to mate with the

color-blind man, there would result, not only normal and color-blind sons, but also color-blind daughters.

QUESTIONS

1. Will you state Bateson's experiment to show clearly that a particular character may be due to the interaction of several heritable factors? Can someone give an experience in breeding rabbits or corn that illustrates the factorial hypothesis?

2. How will you explain the various shades of color that result from the crossing of whites and negroes?

3. What is meant by a sex-linked character?

4. Can you explain the peculiar transmission of color blindness through a female who is herself not color-blind?

CHAPTER VIII

ARE ACQUIRED MODIFICATIONS HERITABLE?

One of the very live questions in heredity at the present time is whether or not acquired modifications can be transmitted from parents to offspring. The term "acquired modification" or "acquired character" is used with a very definite meaning in all discussions of heredity. In one sense all new characters are acquired. If we believe in the derivation of the more complex animals and plants from relatively simple types (the doctrine of evolution), evidently the characters which later animals come to possess are not possessed by the earlier forms from which they are derived. Thus in the early rock strata we find no vertebrate animals; later the vertebrates appeared. The vertebrate character is one, therefore, that was acquired by the animals in due course of time. It is not, in this sense, however, that

the biologist uses the term "acquired character." By "acquired character," or better—"acquired modification," is meant some feature which the animal or plant body takes on directly in response to the changing environment, and it is a question whether such acquired modifications are transmissible.

The older naturalists took this for granted. Thus we find that if certain plants which ordinarily grow in the lowlands are transplanted to an Alpine environment, high up on the mountain, they become dwarfed, frequently acquire a high degree of hairiness, and not uncommonly the blossoms increase in brilliancy. The progeny of such plants manifest the same modifications, and it was taken for granted that they transmit such to their offspring.

Our field corn was originally a tropical plant. The varieties that one finds now in the southern states require a long season for maturation. As the corn plant was introduced gradually farther and farther north it began to ripen its seed more rapidly, until we find such northern varieties as Peep o' Day, produced by the northern seed-

houses, come to maturity in the short summer of these extremely northern states. It looks very much as if the short season had had a direct effect upon the corn, and the remarkable thing is that such breeds of corn, when taken south again, retain their habit of early ripening more or less completely, as also do their offspring. On the face of it, it appears as if this were an example of the acquisition of a new character as a result of environmental influences, and that this acquired modification was transmitted to the progeny. When, however, we examine this case more carefully, it is very evident that other interpretations are possible. In any field of corn there will be found some plants that ripen earlier than others. In other words, there is a degree of variability present in this as in other characters. Evidently, as corn is planted farther and farther north, only the seed from plants that mature early can be gathered for planting next year. The late maturing plant would be nipped by the frost and killed, and would leave no seed. One would, therefore, continually get a selection of

strains that ripen at earlier and earlier times, and the resultant very early ripening variety would come about by the elimination of all those plants that did not have in their germ cells the early ripening trait.

All through the Central West we have one species of chipmunk. In the Rocky Mountain region, however, we have a great many different species. Wherever there is an isolated valley, hemmed in by impassable mountain barriers, there you are very prone to find a species peculiar to that valley. It looks as if, when the mountains were upheaving, some of the chipmunks that originally roamed the entire region were isolated, and had gradually changed their character as the environmental influences of this particular locality had time to operate upon them. Now these new species breed true, and again it looks as if we had the transmission of an acquired modification. But we may interpret the phenomenon in a different way. It may be that the hereditary germ material is subject to wide variation, and that only those varieties have survived whose germinal

variations adapted them to the particular style of environment.

Since it seems impossible to settle this doubtful point by observations in the field, the biologist has had recourse to experiment. There are a number of experiments that have been unconsciously conducted by the race for generations. Chinese women, from time immemorial, have had their feet bound when they were very little girls so as to produce the deformed, but stylish, foot. Here is a modification which has been impressed on the body of the Chinese women repeatedly, and yet Chinese babies are born with as perfect feet as any other babies. It is stylish, among the Flathead Indians, to possess a forehead that slopes back from just over the eyes to a peak at the top of the head. To produce this feature, a board is bound on the head of the growing Flathead Indian baby. In spite of the fact that this custom has obtained for many centuries, the babies persist in coming into the world with perfectly normal heads.

The most noted experiment that seems to give support to the notion that acquired modifications are inherited is the experiment of Brown-Sequard with guinea-pigs. Brown-Sequard so injured the nervous system of adult guinea-pigs that they had frequent epileptic seizures. It was found that the offspring of these animals also had much more frequent attacks of epilepsy than the offspring of normal pigs. But this experiment lacks confirmation. It has been tried by later experimenters without achieving the results that Brown-Sequard claims.

The first serious doubt of the inheritance of acquired characters was raised by Weismann in the latter part of the last century. Weismann, in his study of some of the lower animals, was struck by the fact that those cells in the animal body which ultimately give rise to the eggs or the sperm seem to have a history that is more or less disconnected from and independent of the rest of the organism. We have already seen that any animal or plant originates from one single cell; that by repeated divisions

this cell (fertilized egg) gives rise to the rest of the cells that make up the animal or plant. Most of these cells differentiate as they assume different functions. Thus in the animal we have muscle cells, nerve cells, gland cells, and corresponding differentiations in the tissues of plants. But those cells that are going to give rise to the eggs and sperm are relatively undifferentiated, maintaining more or less completely their embryonic character. To these cells Weismann gave the name of germ cells, to distinguish them from the cells which go to make up the rest of the body, which he called the somatic cells. The protoplasm of the germ cells he designates germ plasm, that of the somatic cells, soma plasm, and Weismann's contention is that the germ plasm is continuous generation after generation. It is the germ plasm that gives rise to the soma plasm, not the reverse, or, to put it in more concrete form, it is the egg which gives rise to the chick, and to the eggs which its body contains, rather than the chick which gives rise to the egg. The diagram (Fig. 7) will make this plainer. The

cells which separate from the germinal material differentiate into the body of the chicken, while the undifferentiated germ cells continue and

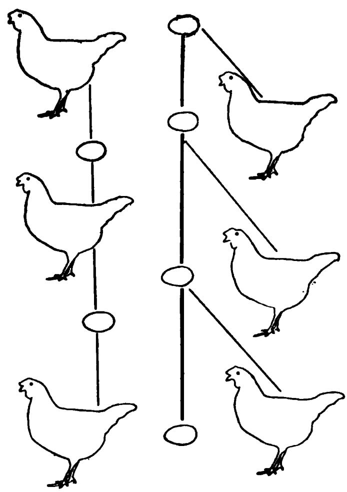


FIG. 7.—At the left the old idea is illustrated that the chicken gives rise to an egg from which comes another chicken that produces an egg, etc. At the right the modern conception is shown: the egg gives rise to more egg-forming material and also to the body of the chicken. The germ plasm is thus continuous.

furnish the eggs out of which the next generation of chickens will develop. It is a mere coincidence that the germ cells are contained within the body of the parent. If this is true, it is evidently difficult to conceive how changes

which affect only the body of the chicken can influence later chickens, because the only direct connection between the chick and its offspring is back through an egg which goes out of existence as it develops into the chick and more of the germ plasm.

In several animals we have evidence of this early separation of the soma plasm from the germ plasm. Even in the four-cell stage of the developing egg of *Ascaris*, a round worm common in the intestine of the horse and hog, the body cells are marked off from the germ cells by the fact that certain portions of the chromosomes disappear in the body cells, while they remain in the germ cell. Thus only one cell of the four continues as germ material, while the other three give rise to the body cells. Similarly, in *Miaster*, one of the flies, the somatic cells are clearly distinguished from the germ cells by the eight-cell stage of the developing egg. And in many other animals we can trace this separation back to an early stage in development. We seem to have, then, fairly positive evidence that Weismann's contention is correct,

and that there is a continuous stream of germ plasm going from parent to offspring, generation after generation, and that this is more or less independent of the body plasm. It is then easy to see why offspring are like their parents; both are produced from the same stuff, the germ plasm.

To see whether or no the body plasm would affect the germ plasm contained in it, this experiment was tried. The ovaries of a black guinea-pig were transplanted to a white pig after the ovaries of the latter animal had been removed. When the wounds had healed, and the animal had recovered perfectly, this white female with ovaries from a black was mated to a white male. Now we know that the offspring should be all white animals, under normal conditions, when two whites are thus mated. If the white female had affected the germ plasm in the transplanted ovaries, something of the same result would be achieved. As a matter of fact, all the young born were black, with no intimation of white, which is the result that would follow from mating a black female to

a white male, since black is the dominant character. Of course experiments of this type must be multiplied before we reach a certain conclusion, but, as far as the evidence goes, it looks as if the body plasm were early set off from the body germ, and that the former had little or no effect upon the germ plasm.

Such a conclusion is also compatible with the results achieved in the experiments cited before, viz., that acquired characters, which are modifications that impress the body plasm only, cannot be transmitted. To put this result in more concrete manner it would mean this: that if a person in whose ancestry tuberculosis had seldom or never occurred should come down with the disease and ultimately die of it, children of such an individual would be no more prone to the disease as far as inheritance is concerned than the children of a person who has not died of tuberculosis. Conversely, this would be true: that if a person in whose ancestry tuberculosis was a very common cause of death should, by hygienic living and wise precautions, avoid tuberculosis, the hereditary

tendency to the disease would yet be transmitted quite as forcefully to the children. This illustration is based on the conception that the tendency to tuberculosis is a distinctly heritable thing. That is not yet conclusively proven, though it is probable. The non-inheritance of acquired characters would mean that the man who has laboriously achieved an education does not thereby make it easier as far as hereditary influences are concerned for his children to achieve an education. They must start at the same point as the parent.

The expression "in so far as hereditary influences are concerned" is repeatedly used because undoubtedly the child of the tubercular parent is handicapped by living in an atmosphere more or less overcharged with tubercular germs, and the child in the cultured home of the educated individual has the advantage of the inspiring and stimulating contact with people of distinct mental ability. We must clearly distinguish, in other words, between physical inheritance and social inheritance. Each generation passes on to the next a mass of social

institutions, culture, and ideals that have gradually been developed at the expense of much effort, so that the child of today finds himself growing up in an environment that makes success along many lines infinitely easier than for a child of several generations ago. This transmission from generation to generation of the body of social customs and achievements may be termed social heredity, but evidently it is quite distinct from the thing which we ordinarily speak of as heredity—the physical transmission of characters from parent to offspring.

While it is generally accepted that no environmental influence can affect the body in such a way as to be transmitted, the environmental influence may directly affect the germ cells. Tower found in experiments on potato beetles that it was possible to produce exceptionally dark animals if the young were reared from the egg in very moist air that was unusually warm, and that, conversely, the animals were very pale if reared in dry cold air. The potato beetle is peculiar in that the germ cells lie

dormant through most of the life-history of the animal, growing rapidly to produce the eggs and sperm during a very short period when the animal is quite mature. If, now, the beetles are kept under the conditions of excessive moisture and high temperature while these germ cells are undergoing rapid multiplication, no effect is produced on the beetles themselves, for they are already mature, but their offspring are exceptionally dark in successive generations. On the contrary, the young reared under these same conditions, but removed before the sex cells go through their period of rapid development, are themselves dark, but their young show no effect of the altered conditions, being normally colored. It is very evident that in the last case we have affected only the growing body; in the former case only the germ cells.

Stockard has made some very interesting experiments with guinea-pigs. By putting guinea-pigs into a cage, the air of which was more or less saturated with the vapor of alcohol, he could habituate the pigs to the use

of alcohol. Numerous pairs of guinea-pigs were subjected to the alcohol, some for brief periods, others for long periods. At the same time other pairs of guinea-pigs from the same litters were kept under normal conditions. It was found that the guinea-pigs that were more or less confirmed drunkards gave birth to a larger number of young than normal pigs, but a high proportion of these young were born dead. A much higher percentage of them died in early life than did the offspring of the normal pigs, a great many of them were born deformed, and many were prone to serious nervous diseases, such as epileptic seizures. Furthermore, it was found that such results followed more commonly when the father was an inebriate than when the mother was addicted to alcohol, if parents were used one of whom was exposed to the influence of the alcohol and the other was normal. Another interesting result followed from the matings of the offspring of inebriate parents when the young so mated were not themselves habituated to the alcohol. The young produced showed the deleterious effects

already mentioned even more than the offspring of alcoholized parents. In other words, the grandchildren suffered more than the children from the debauches of their ancestors. The only conclusion that we care to draw at present is that germ cells evidently may be directly affected by factors in the environment.

Experiments on other animals made in the same way as Stockard's experiments indicate that the results achieved by Stockard do not necessarily obtain in all their details. White rats were tested as follows to determine the rate at which they learned. They were first accustomed to feed at one corner of their cage. Then partitions were set in so that the food was out of sight at the end of a maze of passages. Each rat was tested separately and at first wandered about in a tortuous course in its attempt to find the customary food. In the course of repeated trials day after day it learned to omit some of the unnecessary windings and finally went directly to the food. The length of time it took a rat to learn its way unerringly along the passages to the food was an index of

its educability. It was found that the off-spring of rats accustomed to habits of inebriety learned more readily than those of non-alcoholized rats. Hodge found the reverse to be true for dogs.

So far as the statistics of human inebriety go, it appears that the children of moderate and even of excessive drinkers are not inferior to the general run of children from the same social stratum. It is true, however, that there is a high percentage of defective offspring from parents who are addicted to alcoholic debauches. These apparently contradictory findings are harmonized in this way. Alcoholism is a symptom rather than a cause. It denotes nervous degeneracy. The children from such defective germ plasm are very prone to manifest nervous defects, such as alcoholic mania, insanity, epileptic seizures, imbecility, and so on. This topic will be further discussed in the next chapter. It is touched upon here to make clear this point, that while acquired modifications are not transmissible hereditarily, those influences which affect the body may

also directly affect the germ plasm and produce heritable results.

There is one set of diseases which, while they are not heritable in the sense that they are transmitted through the germ plasm, are yet directly passed from the parent to the offspring. These are some of the venereal diseases, such as syphilis and gonorrhea. They are no more heritable than smallpox or scarlet fever, but since they are diseases of the sex organs, and the child in the process of being born must come in contact with these sex organs, the child is practically certain to catch the disease from its parent. They are exceedingly persistent and readily infectious. While they are commonly passed from individual to individual by the intercourse of the sexes, a perfectly innocent person may get the contagion by using an unclean toilet or merely by personal contact, touching or kissing an individual who is seriously affected with the disease. Gonorrhea is responsible for a very large percentage (probably 80 per cent) of the blindness of infants and for a large percentage of the opera-

tions involving the abdominal organs of women. Syphilis is responsible for more or less of feeble-mindedness and for much insanity, and it probably is the direct cause of locomotor ataxia, of softening of the brain, and a frequent contributing cause to hardening of the arteries and death from the rupture of brain blood vessels.

It is probably safe to say that these diseases are the cause of more misery than all of the other diseases put together. It is difficult to make a cautious statement of their results. Even conservative physicians in writing of their effects are prone to make assertions that read like those of the alarmist. They are undoubtedly spread chiefly by sexual impurity. So appalling are their results that many extreme measures have been advocated to check their havoc. Some states now prescribe that before a marriage can be legally performed both the contracting parties must furnish to the proper authorities a certificate that they are free from venereal diseases. Some states, recognizing the correlation between these diseases and crime, insanity, imbecility, and pauperism, provide

for the segregation of such people and their confinement under conditions which will make the bearing of children impossible. In some states it is incumbent upon the authorities in charge of persons in insane asylums, penitentiaries, and institutions for the feeble-minded to sterilize such as are adjudged to be hopeless cases. But probably the most effective method of dealing with the situation is to bring to young people a realization of the prevalence of such diseases, even among men of the better social classes.

These diseases are curable, but only after prolonged treatment, and then only in a small percentage of the cases treated. The effects of such sins as alcoholism and sexual impurity are transmitted apparently to the children to the third and fourth generation. In the case of the latter disease, at least, the transmission is not the truly hereditary transmission, but the evil effects are just as serious as if it were true inheritance. It is to be noted that the effects of these conditions seldom do run for many generations. The stock is very prone to die

out. The striking biblical passage seems significantly true in this connection.

QUESTIONS

1. Can you give examples of acquired modifications not mentioned in the book?

2. Will you give some examples of the apparent transmission of acquired modifications that are otherwise explicable?

3. Recall Tower's experiments with potato beetles, and then make clear the distinction between the influence of an environmental factor upon the body plasm and upon the germ plasm.

4. What is the evidence that it is possible for alcohol to directly injure the germ cells and so produce deterioration in the offspring?

5. In what way is it possible for the "sins of the fathers" to be visited upon the "children to the third and fourth generation"?

CHAPTER IX

THE INHERITANCE OF HUMAN CHARACTERS, PHYSICAL AND MENTAL

Anyone who undertakes to trace the ancestry of an individual is soon impressed with the fact that it is a difficult task even to find the names of the persons involved three or four generations back; it is much more difficult to determine with certainty their physical and mental characteristics. One can more surely find the pedigree of a horse or hog that he may own than he can of a child in whom he is interested, for we do have registry books for good stock, but none ordinarily for human family relations (in Illinois not even compulsory birth registrations until very recently), so that a child born in this state may not even legally prove his existence or parentage by official records. It is not an easy matter, therefore, to find human data that illustrate the various phases of heredity concerning

which we are reasonably sure in dealing with animals and plants.

Fortunately, there are some studies of the inheritance of physical characters that are quite satisfactory. There is an increasing number of studies of the inheritance of insanity, feeble-mindedness, epilepsy, and alcoholism by the scientific staff of institutions dealing with such cases, and we do have a fairly good mass of material in the lines of descent of the royal families of Europe, where the matings and the characters of the individuals are more or less matters of history. Thanks to the generosity of some men of wealth and foresight, appreciative of the importance of a better knowledge of the laws of human heredity, we have in several countries well-endowed laboratories with expert staffs founded on purpose to study this topic; such are the Galton Laboratory of Eugenics in England and the Eugenics Laboratory of the Carnegie Institution, Cold Springs Harbor, New York.

Occasionally a family is found in which one or more members have five fingers instead of

four; such a condition is known as polydactylism. Sometimes a case is recorded in which a person has fingers with two joints instead of three and a thumb with one joint in place of two (brachydactylism). Such human abnormalities are inherited. There is given on the opposite page a chart (Fig. 8) of a family tree in which brachydactylism is very common; it is based on a study made by Drinkwater. Males in the chart are represented by ♂, females by ♀, matings by =. The circles are of solid color ● in individuals affected with the deformity, open ○ in normal individuals. The character seems to behave like a Mendelian dominant, though one could make no very positive assertion on this point from so few individuals. But it is very evident that such a physical character once in the stock is transmitted generation after generation, reappearing continually in the offspring.

There is presented on p. 127 a chart (Fig. 9) of the transmission of cataract. This disease is characterized by the appearance of an opaque area in the usually transparent parts of the

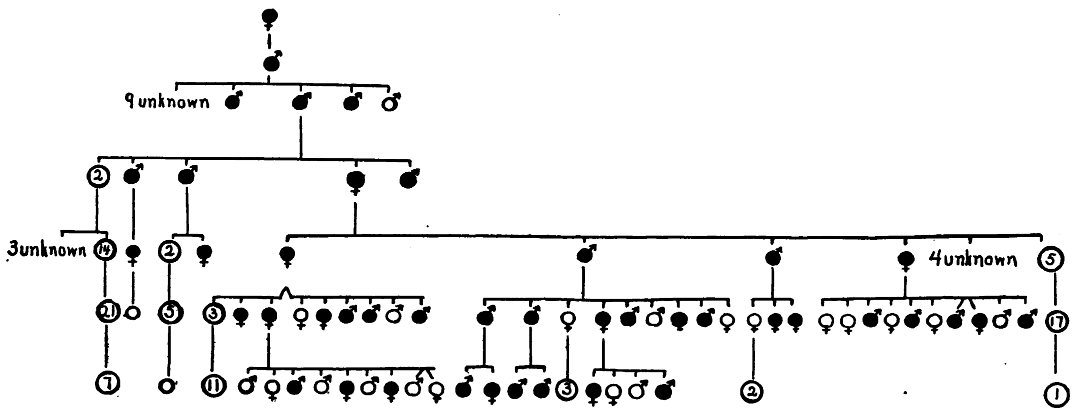


FIG. 8.—Pedigree of a line with brachydactyly, condensed and modified from Drinkwater's chart. It reads thus: A brachydactylous woman has a son, also brachydactylous. He has thirteen children, the condition of nine of whom is unknown; three possess the character; one is normal. One of these four known sons, himself brachydactylous, has six children. The sex of two is not known, but they were not brachydactylous; three sons and one daughter were. And so the family continues. One sees at a glance how the defect continues, generation after generation, not reappearing, however, in the offspring of those who are free from it.

eye, ultimately rendering the person blind. In the particular form of the disease here considered it does not develop until middle life. Clarence Loeb in a study of hereditary blindness published in 1909 tabulated the results of a study of 304 families in which such blindness occurs. There were 1,012 children, of whom 58 per cent were afflicted, which is about the percentage expected when hybrid defectives mate with normal individuals and the defect is a dominant character. Similar extensive studies of congenital deafness and deaf-mutism show that these are similarly heritable, though just how the character behaves is not yet known, for undoubtedly under "deafness" are included a variety of diseased conditions that must be studied separately before we shall know how each is inherited. Care must be taken, too, to distinguish between congenital deafness and blindness—that which inheres in the germ plasm—and those forms, due to accident or contagious disease, which are acquired modifications and so not heritable. Thus measles often produces deafness as one of its after effects.

Persons so rendered deaf would not transmit the affliction to their children any more than they would transmit blindness if the eyes of the parents were put out by accident.

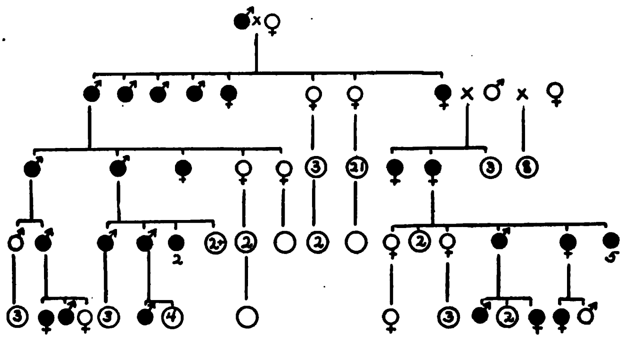


FIG. 9.—Inheritance of one form of cataract. Modified from Nettleship's chart. The diagram reads thus: A man with cataract married a normal woman; of their eight children six were affected with the disease. One of these married an unaffected man; three of the children of this union were normal, sex unrecorded, two defective. This same man married a second wife who was normal; their eight children were all unaffected. So continue reading through five generations.

Feeble-mindedness apparently behaves as a Mendelian recessive. Goddard's studies of the family pedigree of the inmates of the Vineland, New Jersey, institution for the care of the feeble-minded gives us an abundance of material

to show the heritability of this defect and its relation to alcoholism, insanity, syphilis, etc. Briefly, syphilitic infection is a fairly common cause of feeble-mindedness in children. There is a higher percentage of feeble-mindedness in the offspring of alcoholic parents than among those of parents not addicted to it. There seems little or no causal relation between feeble-mindedness and insanity. But aside from feeble-mindedness that may be produced by such causes or by occasional accidents such as falls, blows on the head, there is the great mass of feeble-mindedness that is wholly a matter of heredity.

If a feeble-minded individual comes from parents both of whom are congenitally feeble-minded or who both have a great deal of feeble-mindedness in their ancestry, such a one is taken to be a pure recessive as far as this character is concerned, and his germ cells have a double dose of the factor for feeble-mindedness (FF). When two such persons mate, their offspring would be expected to be all feeble-minded, for all eggs and sperm contain the factor F, and

when any egg is fertilized the person produced is an FF individual. Out of 144 such matings resulting in 482 offspring whose records are known, Goddard found that 476 were feeble-minded. This type of mating as well as others cited below are illustrated in the family pedigrees shown on pages 130 and 131, selected from Goddard's book.

If a person comes from parents one of whom is entirely normal and one is feeble-minded with many feeble-minded ancestors, it is probable that such an individual is a hybrid with germ cells that, as far as this one character is concerned, can be designated NF. Such a person will pass for normal, since feeble-mindedness is recessive. If such a one mates with the type described above (FF), it would be expected that half the offspring would be normal, half feeble-minded. Out of 122 such matings producing 371 children, 193 were found to be feeble-minded, 178 normal, which is remarkably close to expectation considering the difficulty of determining with certainty the real character of the parents. When two individuals of the

NF type mate, their offspring would be expected to give 3 normals to 1 feeble-minded. Out of 146 children produced by 33 such matings Goddard found 39 were feeble-minded.

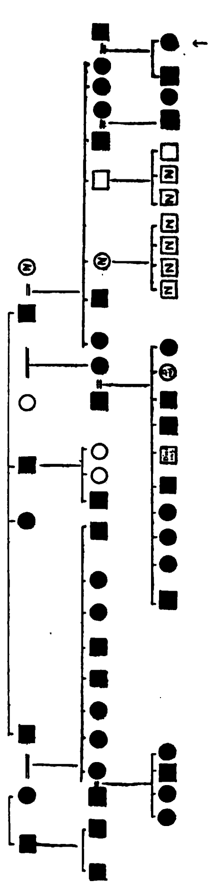


FIG. 10.—Family of Gertie K. (Redrawn from Goddard's *Feeblemindedness*)

The first of Goddard's charts (Fig. 10) illustrates the family tree of Gertie K., a girl of 12 years, with the mental development of a child of 7. Males in this and the following chart are represented by squares, females by circles. Note that this girl has a feeble-minded brother and that both her parents are feeble-minded and see the appalling array of feeble-minded cousins, aunts, uncles, and other relatives. Her grandmother passed for a normal

individual, although it would seem from her children she must have been an NF individual. The second chart (Fig. 11) is quite exactly Mendelian, if we suppose the grandparents were

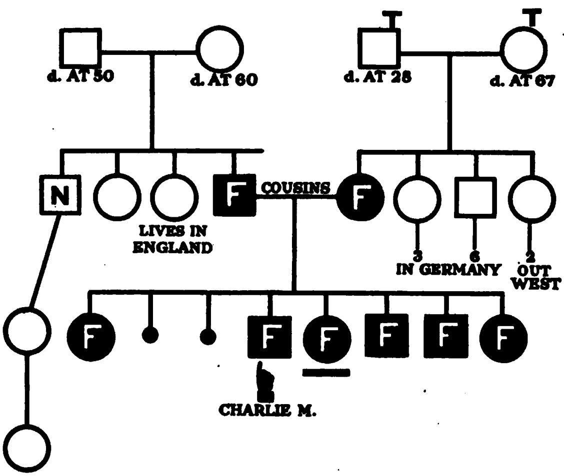


FIG. 11.—Family of Charlie M. (From Goddard's *Feeble mindedness.*)

NF individuals. This case is particularly interesting, for the parents of these six feeble-minded children were high-grade morons, both immigrants. The public must support the children because we have as yet instituted no expert examinations to detect such defectives

among our immigrants in order to refuse them admission to this country.

See what a single unfortunate alliance can produce. A young man to whom Goddard gives the fictitious name of Martin Kallikak had children by a feeble-minded girl in the days before the Civil War. There have been traced some 480 descendants from this mating, and all of them are below normal intelligence. Later this same man married a good Quaker girl, and 496 of the descendants of this marriage have been traced, all of normal mentality. The contrast is strikingly instructive, for the conditions are almost those demanded by a scientific demonstration.

Such cases as those cited are interesting from the standpoint of the student of heredity. They are tremendously significant to the average citizen because there is in the United States a very large feeble-minded population, estimated at 200,000, nine-tenths of whom are at large, free to reproduce their kind, and very prone to interbreed, because the feeble-minded are seldom sought as legitimate mates by persons

of normal mentality. The number of feeble-minded is apparently increasing much more rapidly than the general population. How rapidly, it is impossible to determine, for we have no exact data on the number of feeble-minded; we are not yet awake to the enormity of the problem involved. From these feeble-minded come some 40 per cent of our prostitutes, a fourth of our criminals, and at least a half of the inmates of our almshouses.

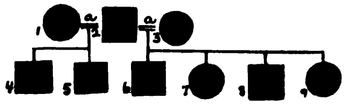
A generation ago the valley of Aosta, in Northern Italy, was overrun with feeble-minded and idiotic individuals of the type known as cretins. It was estimated that fully 60 per cent of the population were affected with this abnormality. A law was passed and enforced segregating the really irresponsible cases and prohibiting the marriage of cretin with cretin. Now the condition has almost disappeared, and it is estimated that only a very small percentage of the population are cretins, these nearly all old, so that this particular form of idiocy will there very soon be a thing of the past. It seems only a rational procedure to accomplish

at least a segregation of feeble-minded in this country, even if no more drastic action is taken. Otherwise the group is bound to be an increasing burden on the community, adding constantly to the tax needed for their support.

Investigations of competent officials in the employ of insane hospitals have accumulated a mass of evidence demonstrating the heritability of many forms of nervous diseases which most commonly behave as recessives. Rosanoff and Orr,[1] in a study of 206 matings between individuals from more or less insane stock, found 1,097 children, 146 of whom died in childhood. There were 351 afflicted offspring to 586 normal. The theoretical expectations, knowing with more or less certainty the character of the parents, was 359 to 578. There are presented (Figs. 12, 13, p. 135) two typical family pedigrees. In the first an insane man was twice married, each time to an eccentric woman, undoubtedly mildly insane. All the offspring were unbalanced. In the second case,

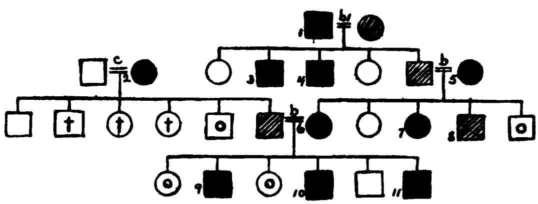
[1] Eugenics Record Office (Cold Spring Harbor, N.Y.), Bulletin, No. 5, 1911.

those distinctly neurotic are indicated in solid color; those having a neurotic element in the



1. Ignorant, "queer."
2. Insane, was in sanitarium, committed suicide.
3. Eccentric, violent temper, ideas of persecution against neighbors.
4. Eccentric, not well-balanced.
5. Alcoholic, lazy, indolent.
6. Dementia præcox, paranoid, in state hospital.
7. Violent temper, queer, extreme dolichocephaly.
8. Defective, cranial malformation.
9. Inferior, "slow."

FIG. 12.—From Rosanoff and Orr, *Inheritance of Insanity*



1. Epileptic.
2. Insane for a time, recovered.
3. Epileptic imbecile.
4. Imbecile.
5. Melancholy in early married life, recovered.
6. Insane five years, was in state hospital, recovered.
7. Insomnia, neuralgia.
8. Daughter had spells of excitement.
9. Feeble-minded.
10. Dementia præcox, katatonic, in state hospital.
11. Died of marasmus, had one convulsion.

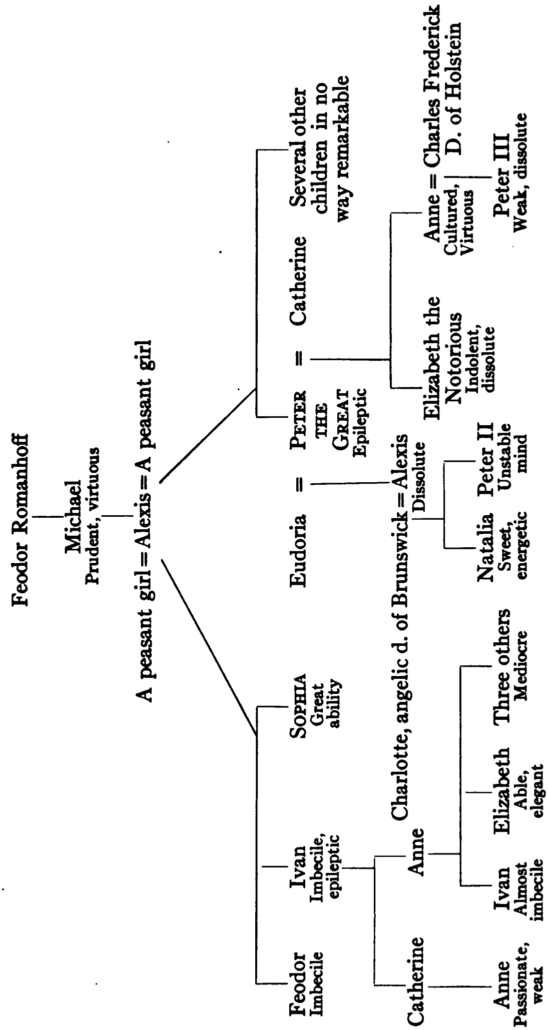
FIG. 13.—From Rosanoff and Orr, *Inheritance of Insanity*

germ material are shaded. It might seem as if insane individuals would scarcely add materially to the general population, since they are

commonly in asylums. Often, however, the inherited insanity does not manifest itself until past middle life, when they have already married and started a family. Moreover, those hybrid individuals in whom the insane tendency is present alongside of the normal determiner appear as normal individuals. Frequently they can be detected only by an examination of the pedigree. If such individuals mate, one-fourth of the offspring would be expected to be insane.

Early modern European history centers about the doings of a few great men and women. Peter the Great of Russia, Ferdinand and Isabella and Charles V of Spain, Frederick the Great of Prussia, Gustavus Adolphus and Charles XII of Sweden, are among the most brilliant of these potent individuals that shaped the destinies of Europe during this period. It is interesting to note how their characters are determined (and through them national destinies are apparently decided in no small measure) by the hereditary concentration of ability due to lucky royal matings,

THE ROMANHOFFS OF RUSSIA: PETER THE GREAT



and how their genius is dissipated by unwise matings.

Peter the Great of Russia came as a brilliant type from a good stock, though with a very evident taint of epilepsy and feeble-mindedness. He himself was an epileptic. His father, grandfather, and great-grandfather had been men of large ability. They had married peasant girls, as was the custom of the czars. Peter's own brothers and sisters were in no way remarkable. His half-sister Sophia was a woman of marked ability, although two of her brothers were imbeciles, one also an epileptic. As will be seen from the pedigree, the epilepsy, imbecility, and mediocrity appear in both Peter's children and grandchildren, as well as in those of his imbecile half-brother, Ivan. It is interesting to note from the pedigree that the feeble-mindedness and epilepsy seem to cling to the males quite persistently. The females of the family are much more apt to be brilliant and virtuous. Peter the Great's own son Alexis was a poor dissolute specimen, and although he married Charlotte, the angelic daughter of a

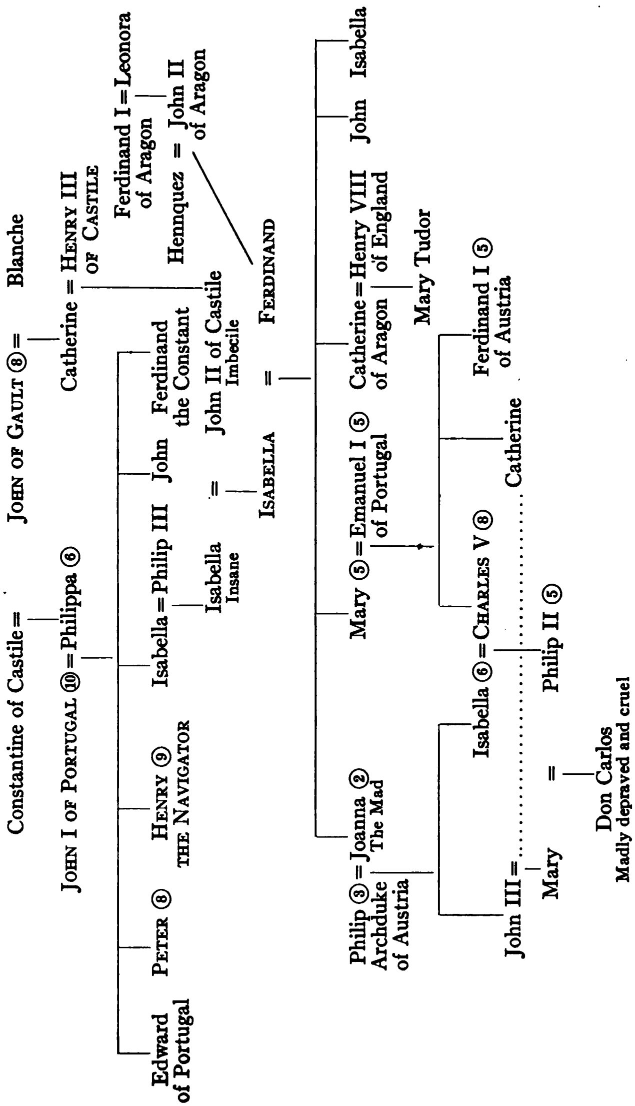
great line, the house of Brunswick, the son of this mating was Peter II, of unstable mind, while the daughter Natalia was as sweet as she was energetic.

Isabella and Ferdinand were both descendants from lines of very great individuals, although in each case there is insanity in the family. Isabella herself comes from an insane mother and an imbecile father, but her grandparents and great-grandparents were well-balanced and able. The data for the charts of these royal families were taken largely from F. A. Wood's *Mental and Moral Heredity in Royalty*, supplemented with information from other sources. He grades the individuals on a scale of 10. Ten represents very high ability, as determined by the comparative amount of space and laudation given to the individual in such standard works as Lippincott's *Biographical Dictionary*. Five out of eight of Isabella's great-grandparents rank very high. John the Great of Portugal, twice her great-grandfather, has a grade of 10. John of Gault, twice her great-grandfather, has a grade of 8, as does also

John of Castile, while Henry III of Castile, one of her grandparents, is designated the model king. Ferdinand I of Aragon, the grandfather of Ferdinand, is a brother of this same Henry III of Castile, and is also an exceedingly able king. Of the children of Ferdinand and Isabella, most were mediocre or distinctly inferior. Joanna was insane. In the next generation, however, appears Charles V, whose reign marked the acme of Spain's greatness, partially due to his own ability, partially due to the momentum of those movements that were instituted by his illustrious grandparents. Charles V married his own cousin, as did also John III. Children of these two matings married, and Don Carlos, child of this latter marriage, was madly depraved and cruel.

When insanity and brilliancy are found in the ancestry, it seems merely a matter of chance as to whether the determiners for greatness will be thrown together in the union of sperm and egg or those for insanity. We can predict with some certainty that, in a large number of offspring, ability will reappear and insanity will

FERDINAND AND ISABELLA

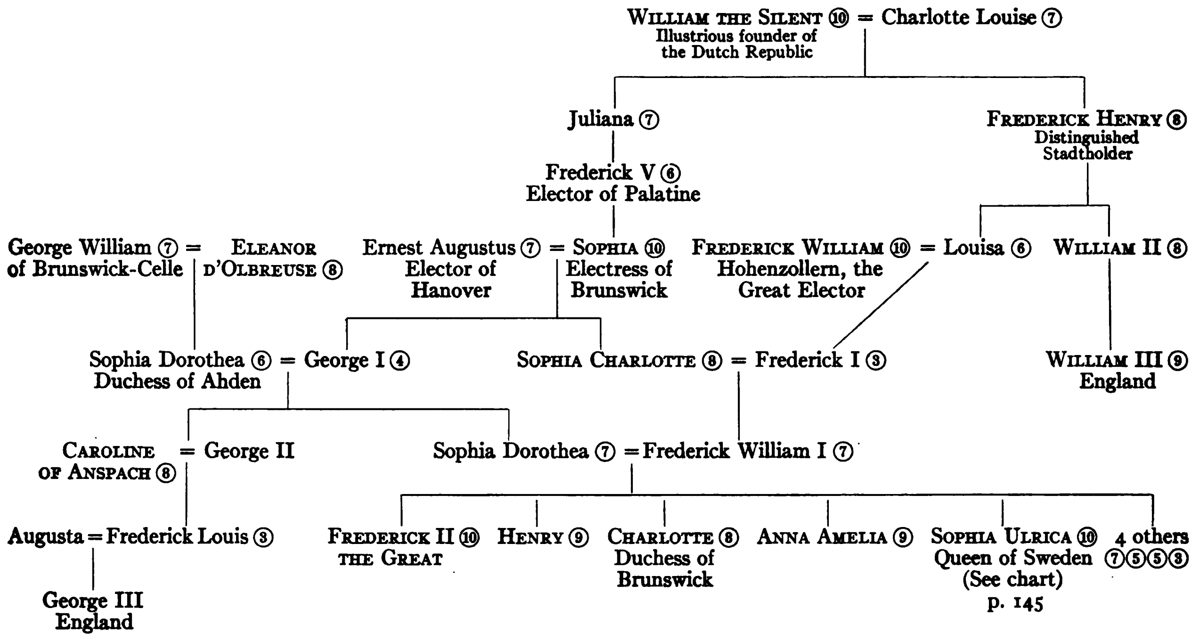


reappear, but just what individual each will strike it is impossible to prophesy without knowing much more definitely the nature of the germ plasm involved. One may say that the convergence of a number of lines of descent from great ancestors toward one individual makes it probable that he will be exceptionally able.

This is nowhere better illustrated than in the family tree of Frederick the Great of the Prussian house of Hohenzollern, as will be seen from the chart on page 143. Of his great-grandparents, three scale 10, one 9, one 8, two 7, and one 6. Not one is below mediocrity, and the majority are of very high grade. Of his fourteen ancestors back three generations, only one is distinctly inferior. Of his brothers and sisters, four are distinctly great, three mediocre, and one inferior.

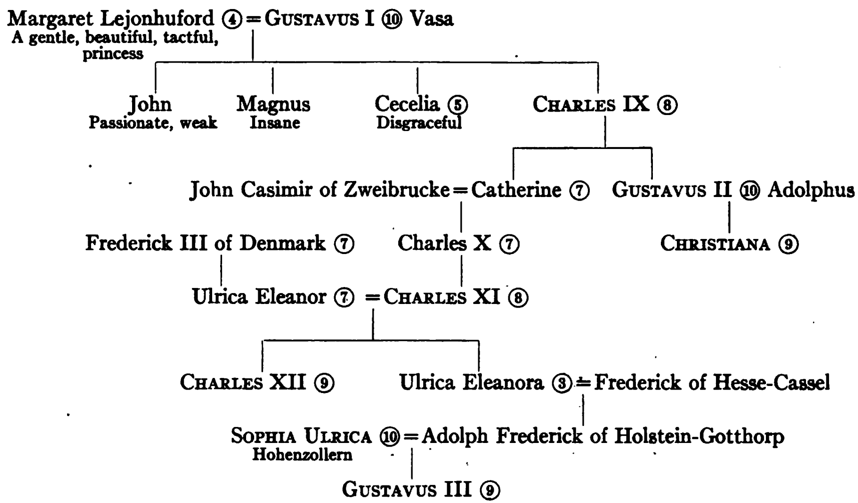
It is interesting to trace the effect of the mating of such splendid stock with another brilliant line, that of the Swedish royal house. Gustavus I, or Gustavus Vasa, is another instance of the brilliant mutant, with some

THE HOHENZOLLERNS OF PRUSSIA: PEDIGREE OF FREDERICK THE GREAT



taint of neurosis. He married a gentle and tactful princess; their son Charles IX was a very able man, although of their three other children one was insane and two weak. The children of Charles IX were both remarkably able. The daughter Catherine becomes the mother of a later succession of kings. Her son Charles X and his son Charles XI were rather mediocre; but Charles XI, with this fine stock behind him, married Ulrica Eleanor (7), granddaughter of Christian IV of Denmark, the most brilliant of all Danish sovereigns, and Charles XII, their son, is pronounced by Voltaire the most remarkable man who ever existed. Charles XII had no children: the succession passed to his sister's son, Adolph Frederick of Holstein-Gotthorp, who married Louisa Ulrica, sister of Frederick the Great of Prussia. The result of this union of two great lines of hereditary ability was Gustavus III, a fit successor of Gustavus Vasa, Gustavus Adolphus, and Charles XII; he was "a prodigy of talents," statesman, poet, dramatist.

CHARLES THE GREAT (XII) OF SWEDEN



QUESTIONS

1. Can you give any example of the inheritance of a physical human character not cited in the text?

2. How would you state the evidence on the probability of the inheritance of mental peculiarities?

3. Does it seem to you likely that the course of history has been affected by the phenomena of heredity? What evidence would you present for your view?

4. Read the delightful story of the betrothal of Isaac and Rebekah (Gen., chap. 24), and note how the idea of keeping the strain pure dominates the narrative. This of course reveals what man had learned by practical experience.

5. Has heredity been powerful in shaping up the destinies of your own particular historical hero?

6. How may the genius be accounted for other than as a result of descent from a line of great ancestors?

CHAPTER X

THE PRACTICAL PROBLEM OF HUMAN HEREDITY

Primitive man sees his world ruled by capricious gods, whose whims and fancies can seldom be accurately anticipated, whose wrath must be appeased, whose favor must be won. Life is a bagatelle, a game of chance, since so many incalculable personalities, gods and demons, fairies and goblins, unexpectedly enter as determining factors. Science has largely relieved man of this dread uncertainty and replaced chance by law and order. Yet we are slow to apprehend this revelation. Instead of inquiring beforehand as to what factors are involved in an undertaking, and as to what the resultant of their orderly interplay is bound to be, we act on sudden impulse, react to uncontrolled desire, and then vainly hope that things will in some way chance to come out right.

This has been notably true in sex relations and in matters of heredity. Possibly, when little or nothing was known of the laws that govern hereditary phenomena, some trust in luck was excusable, and when knowledge of matters pertaining to sex was tabooed and only clandestinely acquired, about the only recourse was blind dependence on chance.

If, then, the preceding chapters have accomplished their purpose, they have left the impression that the young people, who are to be the mothers and fathers of the next generation, have a right to a frank, yet reverent, presentation of reproduction and heredity, at least a presentation sufficient to make them realize that these phenomena are well within the pale of law and order. Now, one may not marry into a family with a persistent tubercular history in the blind hope that luck will prevent the reappearance of the defective tendency in future generations; we know what to expect. We know that insane and feeble-minded stock is prone to reproduce insanity and feeblemindedness, and that, on the other hand,

ability mated with ability tends to reproduce ability. The expert dairyman carefully inquires into the purity of strain and ancestral performance of the animal he mates with his choice cows. The farmer insists on a hog with certified ancestors. We have sense enough to apply such knowledge of heredity as we possess to our farm stock. It seems little enough to ask that we should exercise as much good sense in producing children as we do in the production of hogs and corn. That does not mean that we can apply the method of the cattle pen to human relations, but merely that we adopt caution and intelligent foresight in founding a family commensurate with that used by the wise breeder of plant or animal stock.

Briefly, the knowledge now at our command for this purpose may be summarized as follows. Whenever plants or animals differing from each other in one or more particulars are interbred, the transmission of those factors, whose interplay determines the hereditary characters, is in accordance (generation after generation) with the simple Mendelian laws. Even those cases

that are apparent exceptions, like eye color in the fruit fly and color blindness in men, are found to be explicable as Mendelian phenomena when they are considered as sex-linked characters. So far as our accurate data go, they indicate that the inheritance of human physical characters is truly Mendelian, so that, knowing the hair color, eye color, height, etc., of the parents, one can predict with accuracy the probable characters of the children. Disease tendencies (but not the diseases themselves) usually behave as Mendelian recessives. Certain diseases primarily affecting the sex organs, syphilis and gonorrhea, while not heritable, are communicated from mother to child at time of birth, and from person to person, largely, but not wholly, by impure sexual relations. These diseases are exceedingly virulent, cause untold misery, are more prevalent and more terrible than tuberculosis, and, while curable in a minority of the cases, are often uncured, and hence a source of contagion to innocent persons, especially to wives and children who come in contact with a diseased man.

The facts seem to indicate that abnormal conditions of the nervous system, resulting in alcoholic mania, epilepsy, feeble-mindedness, and insanity, are also heritable, and probably in Mendelian fashion; at least the evidence is sufficient to induce the cautious individual to base action on such a hypothesis. Similarly, the evidence seems to show that mental ability also is heritable, though so many facts are involved in such a complicated thing as "ability" that we may make this assertion in a tentative way only.

With these facts in mind, what policies may be adopted to guide action that aims at an improvement of a family, a race, or a people? We must bear in mind that improving the environment may enlarge opportunity. Training may develop individual capacity to the limit, but that limit is set by the hereditary equipment. The hope of racial improvement is in selective breeding, and this hope must be realized by (1) stimulating reproduction in the best stock, (2) checking it in the poorest. The same method has been effective in man's improvement of domestic plants and animals.

It is one of nature's potent methods for the improvement of all living things, the elimination of the unfit, the reproduction of the fit.

Any farmer would promptly predict the fate of a herd of cattle in which the scrub stock was allowed to breed faster than the pedigreed stock. Yet there is no doubt that in civilized countries large families are the rule among the undesirable elements and the exception in the best stock. Pierson carefully prepared a tabulation showing the relative fertility of various stocks. The mentally defective, criminal, deaf, mute, and degenerate stocks head the list with average families of from five to seven children, while the families of the college-bred professional men average less than two. Cattell gathered data for 917 American men conspicuous in scientific achievement and found they averaged 2.22 children per family, while the average number of children in the families of the parents of these men was 4.66, a decline in the birth-rate in this evidently superior stock of more than one-half in one generation.[1]

[1] *Scientific Monthly*, IV (1917), 252.

Probably the most potent remedy for this situation is the development of a sense of obligation on the part of the really able parents to increase the size of their families as a means of contributing to social improvement, rather than voluntarily restricting the size in the interests of ease and luxury, as seems to be now so prevalent a custom.

Social and economic readjustments, which make possible earlier marriages in the desirable classes, are important factors in any eugenic program, for any social group that marries at twenty will in a few generations outnumber and replace a competing class that marries at thirty. An economy of a few years in the process of education, a larger wage to the young, skilled worker, or a reduction in the cost of the necessities of life by governmental control of the sources of supply, by inventions that cheapen production, by better methods in agriculture—such apparently unrelated factors are really determining influences in the size of families, and so contribute directly to racial improvement by selective breeding.

It is easy to devise methods for checking the increase of the undesirable elements of the population, but not at all easy to enforce these means of control. Segregation under conditions which preclude child-bearing, even sterilization, are devices in actual practice in several states, but as yet public sentiment is not sufficiently aroused to make their enforcement very effective. Consequently such groups as the epileptic, feeble-minded, and insane are still multiplying more rapidly than is even the general run of the population, and much more rapidly than the very select strains. In ancient Athens such defectives were eliminated by the state as a serious menace. Our civilization, more considerate of individual right and less impressed with the welfare of the state, not only lets them live, but hesitates to protect itself from their undue increase.

A certain degree of family pride is a valuable eugenic asset, not the snobbish sort that ostentatiously flounts cheap titles or chance wealth in the faces of its neighbors, but a respect for the family traditions, generation

after generation, of the really fine achievements. The individual who feels that he has behind him a line of immediate ancestors who have accomplished things, men and women who have left a heroic impress on their community, even if it were not a large one, will be inspired to do a man's part in the world.

Finally, it is to be admitted that the eugenist is an idealist, looking forward hopefully toward the things that are to be. How soon they will be accomplished will depend somewhat on how readily Cupid can be induced to submit to established law, somewhat on social readjustments, and somewhat on the good sense of another generation. This generation sees the vision, and has faith that the next will transmute much of it into accomplishment, for

> So nigh is grandeur to our dust,
> So near is God to man,
> When Duty whispers low, "Thou must!"
> The youth replies, "I can."

APPENDIX

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